Documentation Update Package #2

DOE-2.1E, Version 107

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March 2000

This work was partially supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technologies, Building Systems and Materials Division of the U.S. Deptartment of Energy, under Contract No. DE-AC03-76SF00098.

DOE-2.1E, Version 107

Documentation Update Package

This package contains documentation updates to DOE-2.1E (versions 099 and later); we recommend that you incorporate these changes immediately.

Changes to the DOE-2.1E BDL Summary

Page	Section of Documentation or Subprogram	Description of Change
2	Table of Contents	added POLYGON command
8	LOADS (BUILDING-LOCATION command)	added SURF-TEMP-CALC keyword removed ATM-MOISTURE keyword
19	LOADS (EXTERIOR-WALL or -ROOF command)	added POLYGON and INSIDE-SURF-TEMP keywords
22	LOADS (WINDOW command)	added INSIDE-SURF-TEMP keyword
23	LOADS (DOOR command)	added INSIDE-SURF-TEMP keyword
24	LOADS (INTERIOR-WALL command)	added POLYGON and INSIDE-SURF-TEMP keywords
24	LOADS	added POLYGON command
25	LOADS (UNDERGROUND-WALL or -FLOOR command)	added INSIDE-SURF-TEMP keyword added POLYGON keyword
25	LOADS (LOADS-REPORT)	added new report, LV-N, (Surface Vertex Verification Report)
36a	SYSTEM (SYSTEM-EQUIPMENT command)	added keywords for the Cooled Beam system

Changes to the DOE-2.1E Supplement

Page	Section of Documentation or Subprogram	Description of Change
4	Table of Contents	removed table p. 2.65 added Building Geometry, p. 2.127 added Calculation of Inside Surface Temperatures in DOE-2, p. 2.132
7	Table of Contents	added Cooled Beam System description
8	Table of Contents	added report LV-N to Appendix C
2.52	LOADS (BUILDING-LOCATION command)	removed ATM-MOISTURE keyword
2.127	LOADS	added POLYGON section
2.132	LOADS	added “Calculation of Inside Surface Temperatures in DOE-2” section
3.140	SYSTEMS	replaced some SYSTEM-EQUIPMENT default curves, added section “Residential Equipment Part Load Curves for Use in DOE-2”
3.151	SYSTEMS	added Cooled Beam System description
Appendix A -- Hourly Report Variable List		
A.18	VARIABLE-TYPE=u-name of ZONE (cont)	modified Variable #33
A.21	VARIABLE-TYPE=u-name of ZONE (cont)	added Variables #91, 92, 96, 97, 98, 99
A.28	VARIABLE-TYPE=u-name of SYSTEM (cont)	modified Variable #8
Appendix C -- Verification and Summary Reports		
C.27a	Example of Surface Vertex Verification Report	added report LV-N

This replaces page 2 of the DOE-2.1E BDL Summary; command POLYGON has been added.

Table of Contents

This replaces page 8 of the DOE-2.1E BDL Summary; keyword ATM-MOISTURE removed, keyword SURF-TEMP-CALC added.

BUILDING-LOCATION (B-L, 1)

LATITUDE (LAT) (†; -66.5 to 66.5°)
LONGITUDE (LON) (†; -180.0 to 180.0°)
ALTITUDE (ALT) (**0.0**; -1,000.0 to 20,000 ft)
TIME-ZONE (T-Z) (†**;** -12 to all integers)
GROSS-AREA (G-A) (††**;** 0.0 to 10^7 ft^2)
AZIMUTH (AZ) (**0.0;** -360 to 360°)

Time Zone Code	
4 - Atlantic	7 - Mountain
5 - Eastern	8 - Pacific
6 - Central	9 - Yukon
10 - Hawaii	

::

SURF-TEMP-CALC (**NO**; YES, NO)
HOLIDAY (HOL) (**YES**; YES, NO)
DAYLIGHT-SAVINGS (D-S) (**YES**; YES, NO)
GROUND-T (G-T) (‡; -100.0 to 150.0F)
CLEARNESS-NUMBER (C-N) (‡; 0.5 to 1.2)
HEAT-PEAK-PERIOD (H-P-P) (**1,24**; 1 to 24) (all integers*)
COOL-PEAK-PERIOD (C-P-P) (**1,24**; 1 to 24) (all integers*)
X-REF (**0.0**; no limits - ft) [used only in conjunction with the FIXED-SHADE command]
Y-REF (**0.0**; no limits - ft) [used only in conjunction with the FIXED-SHADE command]
SHIELDING-COEF (S-COEF) (**0.24**; 0.0 to 0.32)
TERRAIN-PAR1 (T-P1) (**0.85**; 0.47 to 1.3)
TERRAIN-PAR2 (T-P2) (**0.2**; 0.1 to 0.35)
WS-TERRAIN-PAR1 (W-T-P1) (**1.0**; 0.47 to 1.3)
WS-TERRAIN-PAR2 (W-T-P2) (**0.15**; 0.1 to 0.35)
WS-HEIGHT (W-H) (**33.0**; 0.0 to 1000 ft)
WS-HEIGHT-LIST (W-H-L) (******; 1.0 to 1000)
→ ~~ATM-MOISTURE (ATM-M) (**0.7**; 0.0 to 3.0 in) (list of 12 monthly values)~~
→ ATM-TURBIDITY (ATM-T) (**0.12**; 0.0 to 1.0) (list of 12 monthly values)
FUNCTION (*u-name*,*u-name*)
DAYL-FUNCTION (*u-name*,*u-name*)

Note: HOL=YES ~ U.S. holidays assumed; HOL=NO ~ no holidays assumed
Note: D-S = YES ~ Daylight Savings correction made; D-S = NO, no correction for Daylight Savings
* Only one connected interval may be defined; minimum hour must be less than maximum hour.
** Takes a list of 12 values, 1 per month. Default is WS-HEIGHT.
† Default is taken from weather file
†† Defaults to net area, i.e., the sum of areas of all conditioned SPACEs.
‡ Takes a list of 12 values, 1 per month. Default is taken from weather file.
→ Used only for daylighting calculation.

ALT-HOLIDAYS (1) (A-H) {allows user to input non-US Holidays]
month day month day month day month day … **..**

Only one command allowed per loads input. U-name not allowed. There are no keywords; instead, it takes month-day like the RUN-PERIOD command. Up to 40 month-day pairs may be input. Use of this command replaces all the standard holidays hard-wired into DOE-2. Month is JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC. Day is an integer (1 to 31). Holidays may be entered in any order.

PARAMETER (DEFINE, †)
U-NAME = VALUE, U-NAME = VALUE, etc.

† a maximum of 50 commands in each LOADS, SYSTEMS, PLANT and ECONOMICS with a total of 50 parameters defined.

This replaces page 19 of the DOE-2.1E BDL Summary; added keywords INSIDE-SURF-TEMP and POLYGON.

(=) EXTERIOR-WALL (E-W) or **ROOF** (300)
Note that a set-default for EXTERIOR-WALL will also reset the default for roof.

- **HEIGHT** (H) (−−; 0.0 to 2000.0 ft)
- **WIDTH** (W) (−−; 0.0 to 2000.0 ft**)**
- **CONSTRUCTION** (CONS) u-name

AZIMUTH (AZ) (**0.0°;** -360 to 360°)
TILT (**90°;** 0.0 to 180.0°) ‡‡
::
POLYGON (POLY) u-name
INSIDE-SURF-TEMP (**NO**; YES, NO)
X (0.0; no limits - ft)
Y (0.0; no limits - ft)
Z (0.0; no limits - ft)
MULTIPLIER (M) (1.0; 0.0 to 99.0)
GND-REFLECTANCE (G-R) (**0.2**; 0.0 to 1.0) [see table, next page, for values]
LOCATION (LOC) (†; TOP, BOTTOM, LEFT, RIGHT, FRONT, BACK)
SHADING-SURFACE (S-S) (**NO**; NO, YES)
SHADING-DIVISION (S-D) (**10**; 1 TO 40) (all integers)
SKY-FORM-FACTORS (S-F-F) (--; 0.0 to 1.0)*
and
GND-FORM-FACTORS (G-F-F) (--; 0.0 to 1.0)*
INF-COEF (I-C) (**0.0**; 0.0 to 160.0 units) [see table below for values] ‡
SOLAR-FRACTION (S-F) (†† ; 0.0 to 1.0) [used only when CWF are to be calculated]
INSIDE-VIS-REFL (I-V-R) (**; 0.0 to 1.0) [used only for daylighting calculations]
INSIDE-SOL-ABS (I-S-A) (***; 0.0 to 1.0)
OUTSIDE-EMISS (O-E) (**0.9**; 0.0 to 1.0) †††
FUNCTION (*u-name*,*u-name*)

*	Either both or neither of these should be specified. If not specified, the program will calculate them
**	Default is 0.2 if floor (TILT > 170°), 0.5 if wall (10° ≤ TILT ≤ 170°) and 0.7 if ceiling (TILT < 10°).
***	Default is 0.8 if floor (TILT>170°), 0.5 if wall (10° ≤ TILT ≤ 170°) and 0.3 if ceiling (TILT < 10°).
†	Required if SHAPE keyword is used in the SPACE command. If used, do not use H, W, AZ, X, Y, Z and TILT.
††	If not specified, program will distribute according to total surface area, with floor receiving the greater weight.
†††	Not used for interior walls, underground floors or underground walls.
‡	Used only if INF-METHOD=CRACK in SPACE or SPACE-CONDITIONS
‡‡	Tilt for EXTERIOR-WALL must be input, otherwise defaults to 90°. Tilt for ROOF must be input, otherwise defaults to 0°.

Exterior Wall Infiltration Coefficients

Construction of Wall	$\frac{\text{cfh}}{\text{ft}^2_{\text{wall}}}$	INF-COEF
13” brick with plastered surface	(0.01)	0.002
13” brick, furring, lath, plaster	(0.03)	0.005
Frame wall, lath and plaster	(0.09)	0.016
8-1/2” brick, plain	(5.0)	0.915
16” shingles on shiplap with building paper	(0.5)	0.092
16” shingles on shiplap	(8.0)	1.465
16” shingles on 1x4 boards on 5” center	(40.01)	7.324

This replaces page 22 of the DOE-2.1E BDL Summary; added keyword INSIDE-SURF-TEMP.

(=) WINDOW (W1, 200) [Continued]

INSIDE-SURF-TEMP (**NO**; YES, NO)
::

The followiong keywords are used only for switchable glazing in exterior windows

GLASS-TYPE-SWG (G-T-SW) u-name
SWITCH-CONTROL (SW-C) (**NO-SWITCH**; NO-SWITCH, DIR-SOL-INC, TOT-SOL-INC, DIR-SOL-TR, TOT-SOL-TR, TOT-SOL-HOR, OUTSIDE-TEMP, SPACE-LOAD, DAYLIGHT-LEVEL)
SWITCH-SET-HI (SW-SET-HI) (--; -500.0 to 500.0) [see table below for units] †
SWITCH-SET-LO (SW-SET-LO) (--; -500.0 to 500.0) [see table below for units] †
SWITCH-SCH (SW-SCH) u-name

† Unused for SWITCH-CONTROL=DAYLIGHT-LEVEL

Exterior Wall Infiltration Coefficients

Construction of Wall	$\frac{\text{cfh}}{\text{ft}^2_{\text{wall}}}$	INF-COEF
13” brick with plastered surface	(0.01)	0.002
13” brick, furring, lath, plaster	(0.03)	0.005
Frame wall, lath and plaster	(0.09)	0.016
8-1/2” brick, plain	(5.0)	0.915
16” shingles on shiplap with building paper	(0.5)	0.092
16” shingles on shiplap	(8.0)	1.465
16” shingles on 1x4 boards on 5” center	(40.01)	7.324

SWITCH-CONTROL	Units of SWITCH-SET-HI and -LO (for English and metric runs)
NO-SWITCH	no units used
DIR-SOL-INC	Btu/h-ft^2 [glass]
TOT-SOL-INC	Btu/h-ft^2 [glass]
DIR-SOL-TR	Btu/h-ft^2 [glass]
TOT-SOL-TR	Btu/h-ft^2 [glass]
TOT-SOL-HOR	Btu/h-ft^2
OUTSIDE-TEMP	°F
SPACE-LOAD	Btu/h-ft^2 [glass]
DAYLIGHT-LEVEL	no units used

This replaces page 23 of the DOE-2.1E BDL Summary; added keyword INSIDE-SURF-TEMP.

(=) DOOR (64)

- HEIGHT (H) (--; 0.0 to 40.0 ft)
- WIDTH (W) (--; 0.0 to 1000.0 ft)
- CONSTRUCTION (CONS) u-name of a quick-type (U-value) CONSTRUCTION

INSIDE-SURF-TEMP (**NO**; YES, NO)
MULTIPLIER (M) (**1.0**; 0.0 to 99.0)
SETBACK (SETB) (**0.0**; 0.0 to 10.0 ft)
OVERHANG-A (OH-A) (**0.0**; no limits - ft)
OVERHANG-B (OH-B) (**0.0**; no limits - ft)
OVERHANG-W (OH-W) (**0.0**; no limits - ft) **
and
OVERHANG-D (OH-D) **
LEFT-FIN-A (L-F-A) (**0.0**; no limits - ft)
LEFT-FIN-B (L-F-B) (**0.0**; no limits - ft)
LEFT-FIN-H (L-F-H) (**0.0**; no limits - ft) **
and
LEFT-FIN-D (L-F-D) (**0.0**; no limits - ft) **
RIGHT-FIN-A (R-F-A) (**0.0**; no limits - ft)
RIGHT-FIN-B (R-F-B) (**0.0**; no limits - ft)
RIGHT-FIN-H (R-F-H) (**0.0**; no limits - ft)**
and
RIGHT-FIN-D (R-F-D) (**0.0**; no limits - ft) **
X (**0.0**; no limits - ft)
Y (**0.0**; no limits - ft)
SKY-FORM-FACTORS (S-F-F) (--; 0.0 to 1.0)*
and
GND-FORM-FACTORS (G-F-F) (--; 0.0 to 1.0)*
SHADING-DIVISION (S-D) (**10**; 1 to 40) (all integers)
INF-COEF (I-C) (**0.0**; 0.0 to 500.0 units) [see table below for typical values]
INSIDE-VIS-REFL (I-V-R) (**0.5**; 0.0 to 1.0) [used only for daylighting calculation]
FUNCTION (*u-name*,*u-name)

* Either both or neither of these should be specified. If not specified, the program will calculate them.
** Either both or neither of these should be specified. If not specified, shading calculation will not be done

Door Insulation Coefficients	
Door Configuration	**INF-COEF**
1. Door - Residential 3-ft x -7ft:	
closed with weather stripping	2.4
average use with weather stripping	9.8
average use without weather stripping	12.0
2. Door - Residential 3-ft x -7ft:	
door closed	3.1
door and vestibule open 10% of time	9.3
door open 10% of time	13.5
door open 25% of time	55.0
door open 50% of time	153.0
3. Door - Revolving, average use:	12.0
4. Garage or Shipping Room:	
no use	6.0
average use	60.0

This replaces page 24 of the DOE-2.1E BDL Summary;
keywords INSIDE-SURF-TEMP and POLYGON added; command POLYGON added.

(=) INTERIOR-WALL (I-W, 512)

- **AREA** (A) (−−; 0.0 to 100,000.0 ft^2)
  or
  HEIGHT (H) (−−; 0.0 to 2000.0 ft) ***
  and
  WIDTH (W) (−−; 0.0 to 2000.0 ft**) *****
  or
  LOCATION (LOC) († ; TOP, BOTTOM, LEFT, RIGHT, FRONT, BACK)

- **CONSTRUCTION** (CONS) u-name
  NEXT-TO (N-T) u-name of adjacent SPACE *
  ::
  INSIDE-SURF-TEMP (**NO**; YES, NO)
  POLYGON (POLY) u-name
  INT-WALL-TYPE (I-W-TYPE) (**STANDARD**; STANDARD, AIR, ADIABATIC, INTERNAL)
  TILT (**90°;** 0.0 TO 180.0°) ‡
  SOLAR-FRACTION (S-F) (†† ; 0.0 to 1.0) (list of two) [used only when CWF are to be calculated] †††
  INSIDE-VIS-REFL (I-V-R) (**; 0.0 to 1.0) (list of two) [used only for daylighting calculation] †††
  X (**0.0**; no limits - ft) ***
  Y (**0.0**; no limits - ft) ***
  Z (**0.0**; no limits - ft) ***
  AZIMUTH (AZ) (**0.0**; -360.0 to 360.0°) ***
  INSIDE-SOLAR-ABS (I-S-A) (‡‡ ; 0.0 to 1.0) (list of two) †††

*	Required if INT-WALL-TYPE=STANDARD or =AIR; otherwise unused
**	Default is 0.2 if floor (TILT > 170°), 0.5 if wall (10° ≤ TILT ≤ 170°) and 0.7 if ceiling (TILT < 10°).
***	Used only if either side of the wall is in a space with SUNSPACE=YES
†	Required if SHAPE keyword is used in the SPACE command
††	If not specified, program will distribute according to total surface area with the floor receiving greater weight.
†††	First value in the list of two is for the side of the wall that is in the space in which the wall is defined; second value is for the side of the wall in the NEXT-TO space.
‡	Used only if (a) CWF are being calculated; (b) either side of wall is in a space with DAYLIGHTING=YES; or (c) either side of the wall is in a space with SUNSPACE=YES.
‡‡	Default is (0.8,0.3) if floor (TILT > 170°), (0.5, 0.5) if wall (10° ≤ TILT ≤ 170°) and (0.3,0.8) if ceiling (TILT < 10°).

(=) POLYGON (4000)

2-D Polygon (vertex 1 in 2-D coordinates) (vertex 2 in 2-D coordinates) etc.

Example of an Exterior Wall 2-D Polygon with Three Sides:

```
      TRIANG = POLYGON
               (0,0)(20,0)(10,20) ..
```

Here, (0,0)(20,0)(10,20) are the vertices of the 2-D polygon in the plane of the wall, which is the polygon's local coordinate system

3-D Polygon (vertex 1 in 3-D coordinates) (vertex 2 in 3-D coordinates) etc.

Example of an Exterior Wall that is a 3-D Polygon with Three Sides:

```
      TRIANG = POLYGON
               (8,3.5,6)(28,3.5,6)(18,3.5,26) ..
```

Here, (8,3.5,6)(28,3.5,6)(18,3.5,26) are the vertices of the 3-D polygon in the space coordinate system.

This replaces page 25 of the DOE-2.1E BDL Summary; keywords INSIDE-SURF-TEMP and POLYGON have added. Verification report LV-N has been added to LOADS-REPORT.

(=) UNDERGROUND-WALL (U-W) or **UNDERGROUND-FLOOR** (U-F) (64)

- • **AREA** (A) (--; 0.0 to 100,000.0 ft ^{2})
  - or
    - **HEIGHT** (H) (--; 0.0 to 2000.0 ft)
    - and
    - **WIDTH** (W) (--; 0.0 to 2000.0 ft**)**
  - or
- LOCATION (LOC) († ; TOP, BOTTOM, LEFT, RIGHT, FRONT, BACK)
- • **CONSTRUCTION** (CONS) u-name
- **TILT** (90°**;** 0.0 to 180.0°) ‡
- * **U-EFFECTIVE** (U-EFF) (--; 0.0 to 20.0 Btu/hr-ft^2 - °F) †††

::

INSIDE-SURF-TEMP (**NO**; YES, NO)
POLYGON (POLY) u-name
MULTIPLIER (M) (**1.0**; 0.0 to 99.0)
SOLAR-FRACTION (S-F) (†† ; 0.0 to 1.0) [used only if CWF are to be calculated]
INSIDE-VIS-REFL (I-V-R) (**; 0.0 to 1.0) [used only for daylighting calculations]
INSIDE-SOL-ABS (I-S-A) (***; 0.0 to 1.0)
FUNCTION (*u-name*,*u-name*)

*	If a delayed CONSTRUCTION was input for CWF calculation, U-EFFECTIVE is the appropriate U-value to be used for the hourly simulation
**	Default is 0.2 if floor (TILT > 170°), 0.5 if wall (10° ≤ TILT ≤ 170°) and 0.7 if ceiling (TILT < 10°).
***	Default is 0.8 if floor (TILT >170°), 0.5 if wall (10° ≤ TILT ≤ 170°) and 0.3 if ceiling (TILT < 10°).
†	Required if SHAPE keyword is used in the SPACE command.
††	If not specified, program will distribute according to total surface area, with floor receiving the greater weight.
†††	Used only for automatic calculation of Custom Weighting Factors.
‡	Tilt for UNDERGROUND-FLOOR must be input, otherwise defaults to 180°. A set-default for UNDERGROUND-WALL will also reset the default for UNDERGROUND-FLOOR.

BUILDING-RESOURCE (B-R, 1)
See the PLANT-ASSIGNMENT command in SYSTEMS, p. 42.

LOADS-REPORT (L-R, 1)
VERIFICATION (V) (--; LV-A, LV-B, ... LV-N, ALL-VERIFICATION) (list)
SUMMARY (S) (**LS-D**; LS-A, LS-B, ..., LS-L, ALL-SUMMARY) (list)
REPORT-FREQUENCY (R-F) (**HOURLY**; HOURLY, DAILY, MONTHLY, YEARLY)
HOURLY-DATA-SAVE (H-D-S) (**NO-SAVE**; BINARY, FORMATTED)
See page 100 for a brief description; Chapter III of the *Reference Manual (2.1A)* for definitions, and Appendix C of the *Supplement (2.1E)* for a full description of all reports.

= REPORT-BLOCK (R-B, 64)
• VARIABLE-TYPE (V-T) (--; GLOBAL, END-USE, BUILDING, u-name of SPACE, u-name of ROOF or EXTERIOR-WALL, u-name of WINDOW, u-name of DOOR)

• VARIABLE-LIST (V-L) (--; code numbers) (list)
[for code number list see Appendix A of the *Supplement (2.1E*]*)*

This page of keywords for the Cooled Beam System type should be added to the list of keywords under the SYSTEM-EQUIPMENT command in the DOE-2.1E BDL Summary. Please insert it as page 36a.

Under the SYSTEM-EQUIPMENT Command:

New keywords, specific to the Cooled Beam system, have been added to the command SYSTEM-EQUIPMENT. Basically all of these keywords can be considered product data whose values should be allowed to default or be obtained from the manufacturer. Except for BEAM-WATER-T-IN and BEAM-WATER-T-OUT the keywords are unit-less or always in metric.

= SYSTEM-EQUIPMENT (S-EQ, 50) [Continued]

BEAM-TYPE (**ACTIVE;** ACTIVE, PASSIVE)
BEAM-WATER-T-IN **(59F; range) (15C; range)**
BEAM-WATER-T-OUT (**62.6F; range) (17C; range)**
BEAM-A **(15.3)**
BEAM-A **(0.171)**
BEAM-AREA **(5.422)**
BEAM-D **(0.0145)**
BEAM-KIN **(2.0)**
BEAM-K1 **(0.005)**
BEAM-N **(0.4)**
BEAM-N1 **(0.0)**
BEAM-N2 **(0.84)**
BEAM-N3 **(0.12)**

This sheet replaces page 4 of the table of contents for the DOE-2.1E Supplement.

This sheet replaces page 7 of the table of contents for the DOE-2.1E Supplement.

PLANT

This sheet replaces page 8 of the table of contents for the DOE-2.1E Supplement.

This page replaces 2.52 of the DOE-2.1E Supplement.

Daylighting Commands and Keywords

BUILDING-LOCATION

ATM-MOISTURE is no longer used; it is now calculated hourly from dewpoint temperature in DOE-2.1E version 099 and later.

~~ATM-MOISTURE~~ ~~is a list of twelve monthly values, given in inches, of the amount of precipitable moisture in the atmosphere. The values should be chosen from Table 2.6, p. 2.65. If the location being analyzed is not in Table 2.5, choose values for a location with a similar climate.~~

~~If a similar climate cannot be found, a set of twelve constant monthly values can be assigned according to the following climate types:~~

~~Climate Type~~	~~Atmospheric Moisture (in.)~~
~~Desert (dry air)~~	~~0.4~~
~~Temperate~~	~~0.7 (default)~~
~~Tropical (humid air)~~	~~1.3~~

ATM-TURBIDITY is used only for weather files without measured solar data (TRY for example). Not needed for weather files that do have measured solar data, such as TMY, TMY2 and WYEC.

ATM-TURBIDITY Takes a list of twelve monthly values of atmospheric turbidity (a measure of the amount of aerosols, i.e., particulate pollutants in the atmosphere). The values should be chosen from Table 2.6, p. 2.67. If the location being analyzed is not in this table, choose values for a location with a similar level of atmospheric pollution.

If a similar climate cannot be found, a set of twelve constant monthly values can be assigned according to the following categories:

Category	Atmospheric Turbidity
Rural Area	0.07
Urban Area	0.12 (default)
Industrial Area	0.16

Note: ATM-TURBIDITY is used by the program to calculate the luminance of clear skies.

BUILDING-SHADE and FIXED-SHADE

SHADE-VIS-REFL is the visible reflectance of that side of a BUILDING-SHADE or FIXED-SHADE from which the outward normal points (see text). The other side of the shading surface is assumed to be black, i.e., to have zero reflectance.

SHADE-GND-REFL is the visible reflectance of the ground in the vicinity of the BUILDING-SHADE or FIXED-SHADE.

Please add this section to the DOE-2.1E Supplement, after p. 2.126.

Polygons

Exterior walls, interior walls and underground surfaces can now be described as either two-dimensional (2-D) or three-dimensional (3-D) polygons with three or more sides. This applies to the commands EXTERIOR-WALL, ROOF, INTERIOR-WALL, UNDERGROUND-WALL and UNDERGROUND-FLOOR. Previously, these surfaces had to be rectangular. (As before, windows, doors and building shades must be rectangular.)

2-D Polygons

You specify 2-D polygons by using the POLYGON command and the POLYGON keyword. In addition, X, Y, Z, AZIMUTH and TILT can be used to position and orient the polygon in the space coordinate system. This is illustrated in the following example and in Figure 1.

<u>Example - Exterior Wall 2-D Polygon with Three Sides</u>

```
TRIANG3 = POLYGON
          (0,0) (20,0) (10,20) ..
EW-1 =    EXTERIOR-WALL
          POLYGON = TRIANG3
          X=8 Y=3.5 Z=6
          AZIMUTH=180
          TILT=90
         .....
```

Here:

(0,0), (20,0) and (10,20)	are the vertices of the 2-D polygon in the plane of the wall, which is the polygon’s local coordinate system.
X,Y and Z	are the coordinates of the origin of the polygon's local coordinate system in the space coordinate system. This origin is the first vertex of the polygon, in this case (0,0).
TILT	is the angle between the z-axis of the space coordinate system and the polygon outward normal, which is a vector, perpendicular to the plane of the polygon, that points toward you as you face the polygon. (The polygon outward normal is also defined as the cross product between the vector from vertex 1 to vertex 2 and the vector from vertex 2 to vertex 3. It is also the cross product of the x and y axes of the polygon's local coordinate system.) A vertical polygon has TILT = 90. A horizontal, upward-facing polygon (e.g., a horizontal roof) has TILT=0. A horizontal, downward-facing polygon (e.g., an exposed floor) has TILT=180.
AZIMUTH	is the angle, measured clockwise, between the x-axis of the space coordinate system and the projection of the polygon outward normal onto the space x-y plane.

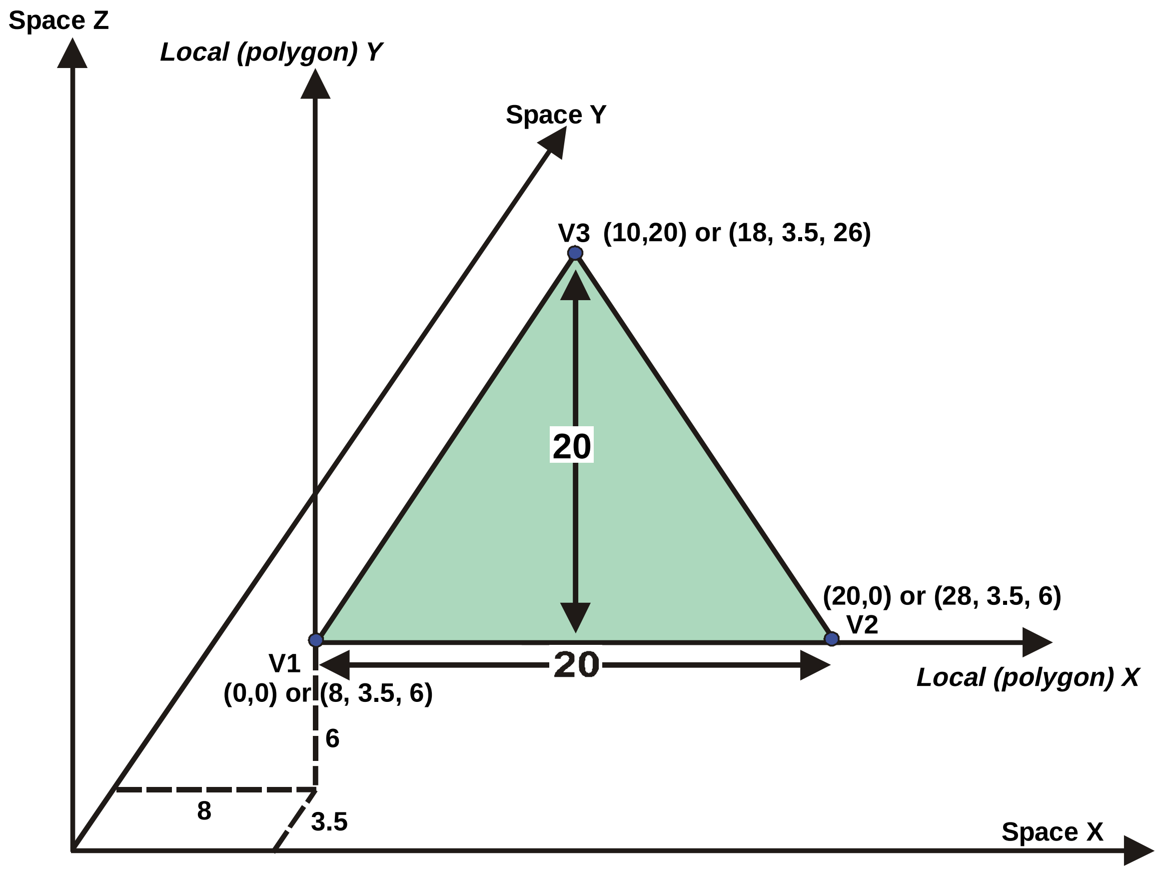

Figure 1: ***Triangular wall entered as a polygon with TILT=90 and AZIMUTH=180, located at X=8, Y=3.5 and Z=6 in the space coordinate system. The triangle has a base of 20 and a height of 20. When entered as a 2-D polygon the vertex locations are (0,0), (20,0) and (10,20) in the polygon's <u>local coordinate system</u>. When entered as a 3-D polygon the same vertices are located at (8, 3.5, 6), (28, 3.5, 6) and (18, 3.5, 26) in the <u>space coordinate system</u>.***

Figure 2 shows how to locate a window (or a door) on a polygonal wall. (Note that windows and doors must be rectangular and cannot be entered as polygons.) You position the window in the polygon's local coordinate system. The window's X and Y values are with respect to the first vertex of the polygon to which the window is attached. In Figure 2a we have chosen the origin of the local coordinate system to be at the first vertex of the polygon (i.e., (0,0)). The lower left hand corner of the window is at X=8, Y=4. Example input in this case is:

<u>Example - Window on a 2-D Polygonal Wall</u>

```
TRIANG4 =   POLYGON
            (0,0) (24,0) (12,16) ..
EW2 =       EXTERIOR-WALL
            POLYGON=TRIANG4 .....
WIN1 =      WINDOW
            X=8
            Y=4
            HEIGHT=4
            WIDTH=7
     .....
```

In Figure 2b, the first vertex of the wall is at (6,6), so that the polygon is displaced in its local coordinate system. The lower left hand corner of the window is at X=14, Y=10. Example input in this case is:

Example - Window in a Displaced 2-D Polygon

```
TRIANG4 = POLYGON
          (6,6) (30,6) (18,24) ..
EW2 =     EXTERIOR-WALL
          POLYGON=TRIANG4 .....
WIN1 =    WINDOW  X=14
          Y=10
          HEIGHT=4
          WIDTH=7
          .....
```

To avoid confusion, we recommend that you always choose the first vertex of the polygon to be at (0,0), as in Figure 2a. This means that when you locate the window it is with respect to this first polygon vertex.

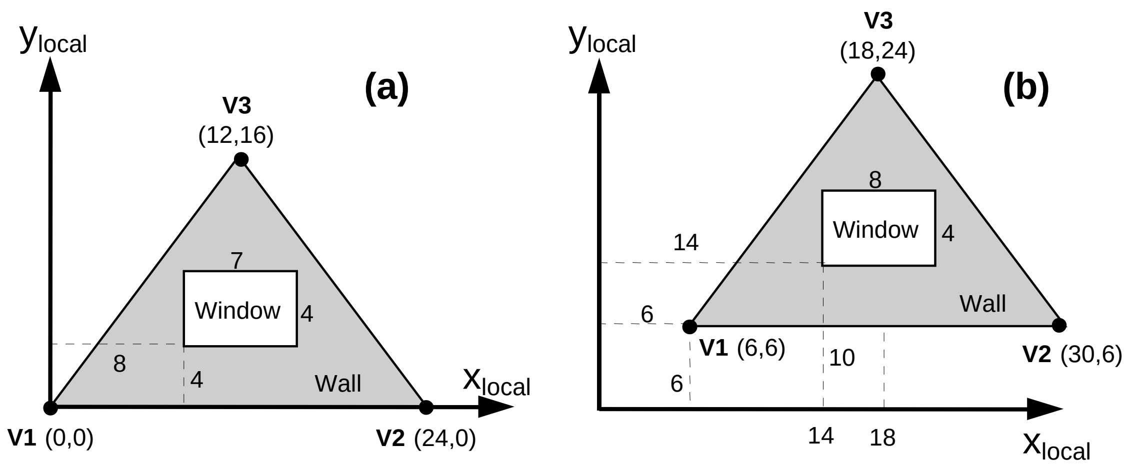

Figure 2: ***Locating a window in a 2-D polygonal wall. The X and Y values of the lower left corner of the window are given in the polygon's local coordinate system. In (a), the first vertex of the polygon coincides with the origin of the local coordinate system. In (b), the first vertex of the polygon is displaced from the origin of the local coordinate system.***

3-D Polygons

For 3-D polygons you give the (X,Y,Z) location of each vertex in the space coordinate system.

Example - Exterior Wall 3-D Polygon with Three Sides

```
p_3d = POLYGON (8,3.5,6) (28,3.5,6) (18,3.5,26)
```

This is the same triangle as shown in Fig. 1.

The X and Y values of a window or door attached to a 3-D polygon are with respect to the first vertex of the polygon.

To specify a polygon with respect to the building coordinate system do the following:

1) use a 3-D polygon
2) use the building coordinate system to specify the vertices of the polygon
3) make the space and building coordinate systems coincide by setting X=0, Y=0, Z=0, AZIMUTH=0 (these are the defaults in the SPACE command)
4) in the EXTERIOR-WALL, etc., command set X=0, Y=0, Z=0 (these are the defaults)

Example - Comparing Simple Rectangle Input with 2-D and 3-D Polygon Input

In the following example EXTERIOR-WALL surfaces ew1, ew2, ew3 have identical geometries.

1. Simple rectangle input:
```
ew1 = EXTERIOR-WALL  X=0 Y=0 Z=0 H=40 W=80 AZIMUTH=180 TILT=90
               ...
```

2. 3-D polygon input:
```
p_3d = POLYGON  (0,0,0) (80,0,0) (80,0,40) (0,0,40) ..
ew2 = EXTERIOR-WALL  POLYGON=p_3d
               ...
```

3. 2-D polygon input:
```
p_2d = POLYGON  (0,0) (80,0) (80,40) (0,40) ..
ew3 = EXTERIOR-WALL  POLYGON=p_2d X=0 Y=0 Z=0 AZIMUTH=180 TILT=90
               ...
```

General Rules for 2-D and 3-D Polygons

1. A polygon must have 3 or more vertices.
2. Vertices are defined in counter-clockwise order when viewed from outside of the space to which they belong. This means that in going from Vertex 1 to Vertex 2 to Vertex 3, etc., your right hand side must always be outside of the polygon. One effect of this rule is that polygons with sides that cross (“figure 8” shapes, for example) are not allowed.
3. Two or more identical vertices are not allowed.
4. Three or more vertices on the same line are not allowed.
5. For 3-D polygons, all vertices must be in the same plane.

Surface Vertex Verification Report

A new Loads verification report, LV-N, gives the coordinates in the building coordinate system of the vertices of all walls and windows. Here is an example.

Surface Vertex Verification Report – LV-N (example)

```
LBL RELEASE OCT 1993       version : 2.1E-107
1˝
      *   1 * diagnostic  WARNINGS ..  $ --- file : ts-poly1.inp ---
      *   2 * input  LOADS ..
1
                        L D L   P R O C E S S O R   I N P U T   D A T A
                               Thu Feb 17 15:23:59 2000LDL RUN  1
      *   3 *
      *   4 * run-period         JAN 1 1974  thru  JAN 2 1974  ..
      *   5 * building-location  latitude=42.0  longitude=88.0
      *   6 *                    altitude=610 time-zone=6   azimuth=30.0  ..
      *   7 * loads-report    verification=(LV-N,LV-C,LV-D,LV-H)
      *   8 * $               dump-options=(STD-FILES,SIMULATION)
      *   9 *       ..
      *  10 *
      *  11 * CONS1 =    construction  u=1.1  ..
      *  12 * GT1 = glass-type  glass-type-code = 3  ..
      *  13 *
      *  14 * PS =  polygon  (0,0,0)   (80,0,0)  (80,0,40)  (0,0,40)  ..
      *  15 * PS_2D =    polygon  (0,0)     (80,0)    (80,40)    (0,40)    ..
      *  16 * PE =  polygon  (80,0,0)  (80,30,0) (80,30,40) (80,0,40) ..
      *  17 * PE_2D =    polygon  (0,0)     (30,0)    (30,40)    (0,40)    ..
      *  18 * P3 =  polygon  (80,0,0)  (80,60,0) (80,60,40) (80,30,70) (80,0,40)  ..
      *  19 * P4 =  polygon  (0,60,0)  (0,0,0)   (0,0,40)   (0,30,70)  (0,60,40)  ..
      *  20 * PS_2DY=    polygon  (0,0)     (80,0)    (80,40)    (0,40)  ..
      *  21 *
      *  22 * $ Note: EW0 , EW1 , EW2 are identical.
      *  23 *
      *  24 * SPX = space  area=1000  volume=10000  x=100  y=200  z=300  ..
      *  25 *   EWXS0 =  e-w  h=40  w=80  azimuth=180  tilt=90  cons=CONS1 ..
      *  26 *     WINXS0 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  27 *   EWXS1=   e-w  Polygon=PS         cons=CONS1 ..
      *  28 *     WINXS1 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  29 *   EWXS2 =  e-w  Polygon=PS_2D  x=0 y=0 azimuth=180 tilt=90 cons=CONS1 ..
      *  30 *     WINXS2 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  31 *   EWXE0 =  e-w  x=80 y=0 h=40  w=30  azimuth=90  tilt=90  cons=CONS1 ..
      *  32 *     WINXE0 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  33 *   EWXE1 =  e-w  Polygon=PE         cons=CONS1 ..
      *  34 *     WINXE1 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  35 *   EWXE2 =  e-w  Polygon=PE_2D x=80 y=0 azimuth=90 tilt=90 cons=CONS1 ..
      *  36 *     WINXE2 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  37 *   EWX4 =   e-w  Polygon=P3         cons=CONS1 ..
      *  38 *   UWX5 =   u-w  Polygon=P3         cons=CONS1 ..
      *  39 *   IWX1 =   i-w  Polygon=P3  next-to=SPY  cons=CONS1 ..
      *  40 *
      *  41 * SPY = space  area=1000  volume=10000  x=1000  y=2000  z=3000  ..
      *  42 *   EWY1 =   e-w  Polygon=PS_2DY  x=0 y=0 azimuth=180 tilt=90 cons=CONS1 ..
      *  43 * end ..
      *  44 * compute loads  ..
      *  45 * stop ..
1                                                                                        2.1E-107  Thu Feb 17 15:23:59 2000LDL RUN 1

 REPORT- LV-N  DETAILS OF GEOMETRY DATA IN BUILDING COORDINATES
 SPACE.................... (SPACE ORIGIN)
     WALL................. (VERTEX1) (VERTEX2) (...)
         WINDOW........... (VERTEX1) (VERTEX2) (...)
 ------------------------------------------------------------------------------------------------------------------------------
SPX .................... . (  100.0   200.0   300.0)
     EWXS0   ............. (  100.0   200.0   340.0) (  100.0   200.0   300.0) (  180.0   200.0   300.0) (  180.0   200.0   340.0)
         WINXS0  ......... (  102.0   200.0   307.0) (  102.0   200.0   304.0) (  108.0   200.0   304.0) (  108.0   200.0   307.0)
     EWXS1   ............. (  100.0   200.0   300.0) (  180.0   200.0   300.0) (  180.0   200.0   340.0) (  100.0   200.0   340.0)
         WINXS1  ......... (  102.0   200.0   307.0) (  102.0   200.0   304.0) (  108.0   200.0   304.0) (  108.0   200.0   307.0)
     EWXS2   ............. (  100.0   200.0   300.0) (  180.0   200.0   300.0) (  180.0   200.0   340.0) (  100.0   200.0   340.0)
         WINXS2  ......... (  102.0   200.0   307.0) (  102.0   200.0   304.0) (  108.0   200.0   304.0) (  108.0   200.0   307.0)
     EWXE0   ............. (  180.0   200.0   340.0) (  180.0   200.0   300.0) (  180.0   230.0   300.0) (  180.0   230.0   340.0)
         WINXE0  ......... (  180.0   202.0   307.0) (  180.0   202.0   304.0) (  180.0   208.0   304.0) (  180.0   208.0   307.0)
     EWXE1   ............. (  180.0   200.0   300.0) (  180.0   230.0   300.0) (  180.0   230.0   340.0) (  180.0   200.0   340.0)
         WINXE1  ......... (  180.0   202.0   307.0) (  180.0   202.0   304.0) (  180.0   208.0   304.0) (  180.0   208.0   307.0)
     EWXE2   ............. (  180.0   200.0   300.0) (  180.0   230.0   300.0) (  180.0   230.0   340.0) (  180.0   200.0   340.0)
         WINXE2  ......... (  180.0   202.0   307.0) (  180.0   202.0   304.0) (  180.0   208.0   304.0) (  180.0   208.0   307.0)
     EWX4................. (  180.0   200.0   300.0) (  180.0   260.0   300.0) (  180.0   260.0   340.0) (  180.0   230.0   370.0)
                           (  180.0   200.0   340.0)
     UWX5................. (  180.0   200.0   300.0) (  180.0   260.0   300.0) (  180.0   260.0   340.0) (  180.0   230.0   370.0)
                           (  180.0   200.0   340.0)
     IWX1................. (  180.0   200.0   300.0) (  180.0   260.0   300.0) (  180.0   260.0   340.0) (  180.0   230.0   370.0)
                           (  180.0   200.0   340.0)
 SPY ..................... ( 1000.0  2000.0  3000.0)
     EWY1................. ( 1000.0  2000.0  3000.0) ( 1080.0  2000.0  3000.0) ( 1080.0  2000.0  3040.0) ( 1000.0  2000.0  3040.0)
1                                                                                   DOE-2.1E-107  Thu Feb 17 15:23:59 2000LDL RUN  1
```

Please add this section to the DOE-2.1E Supplement, after p. 2.131.

Revised article from the Building Energy Simulation User News, Vol. 20, No. 2 (Summer 1999)
Originally appeared in Vol. 16, No. 2 (Summer 1995),

Calculation of Inside Surface Temperatures in DOE-2

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Introduction

The present version of *DOE-2.1E* does not calculate the inside surface temperatures because of the weighting factor approach [1]. But the wall and window inside surface temperatures are important to estimate the radiant temperature as one of the key elements in a thermal comfort evaluation. Therefore, in the frame of the Swiss national project NEFF 640, a model which calculates the surface temperatures has been developed and the required FORTRAN routines have been written. The work was partly performed at the Lawrence Berkeley National Laboratory in cooperation with the Simulation Research Group.

Model

The model is based on an energy balance on the wall surface. The different heat fluxes are shown in Fig. 1. The program *DOE-2.1E* does not take the radiative heat exchange between the room surfaces $\dot{q}_w$ separately into account, but as shown in Fig. 2, a combined convective and radiative film coefficient h is taken into consideration.

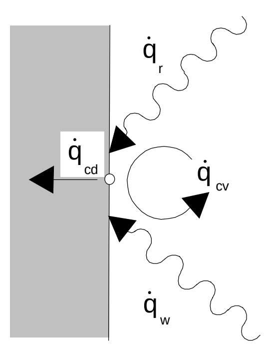


Fig. 1 *Heat fluxes at the wall surface*

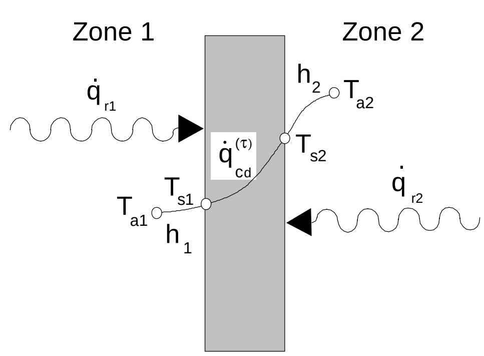


Fig. 2 *Temperature distribution and radiant heat flux for an interior wall (DOE-2.1E model).*

The flux of heat conduction at the wall surfaces is described by the response factors [1] as follows:

$$\dot{q}_{cd1}^{(\tau)} = \sum_{i=0}^{n} X_i^{'} \cdot T_{s1}^{(\tau - i \cdot \Delta\tau)} - \sum_{i=0}^{n} Y_i^{'} \cdot T_{s2}^{(\tau - i \cdot \Delta\tau)} + CR \cdot \dot{q}_{cd1}^{(\tau - \Delta\tau)} \quad (1)$$

$$\dot{q}_{cd2}^{(\tau)} = \sum_{i=0}^{n} Y_i^{'} \cdot T_{s1}^{(\tau - i \cdot \Delta\tau)} - \sum_{i=0}^{n} Z_i^{'} \cdot T_{s2}^{(\tau - i \cdot \Delta\tau)} + CR \cdot \dot{q}_{cd2}^{(\tau - \Delta\tau)} \quad (2).$$

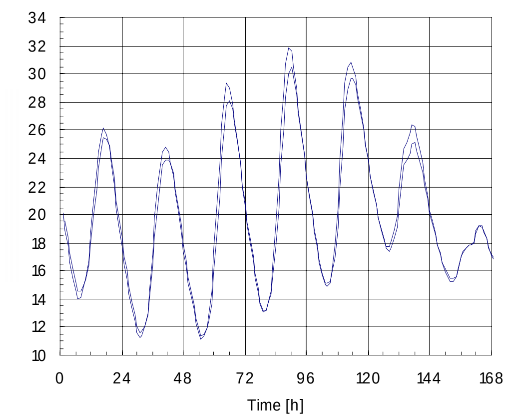
The surface temperatures can be calculated from an energy balance on both sides of the wall:

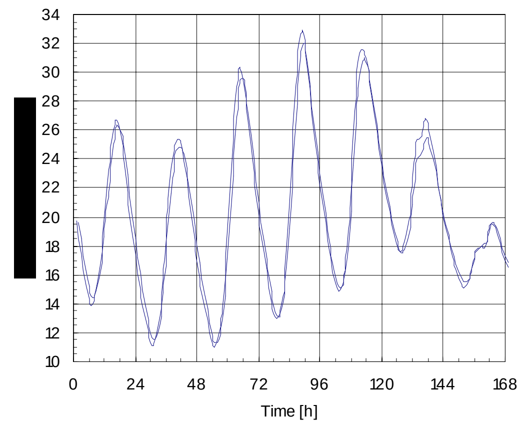
$$\begin{bmatrix} -X_0^{'}-h_1 & Y_0^{'} \\ Y_0^{'} & -Z_0^{'}-h_2 \end{bmatrix} \cdot \begin{pmatrix} T_{s1} \\ T_{s2} \end{pmatrix} = \begin{bmatrix} \sum_{i=1}^{n} X_i^{'} \cdot T_{s1}^{(\tau - i\cdot\Delta\tau)} - \sum_{i=1}^{n} Y_i^{'} \cdot T_{s2}^{(\tau - i\cdot\Delta\tau)} + CR \cdot \dot{q}_{cd1}^{(\tau-\Delta\tau)} - h_1 \cdot T_{a1} - \dot{q}_{r1} \\ -\sum_{i=1}^{n} Y_i^{'} \cdot T_{s1}^{(\tau - i\cdot\Delta\tau)} + \sum_{i=1}^{n} Z_i^{'} \cdot T_{s2}^{(\tau - i\cdot\Delta\tau)} - CR \cdot \dot{q}_{cd2}^{(\tau-\Delta\tau)} - h_2 \cdot T_{a2} - \dot{q}_{r2} \end{bmatrix} \quad (3).$$

The right side of the system of equations (3) only contains surface temperatures and conduction heat fluxes from previous time steps. The zone air temperature and the radiative heat flux to the wall for the current time step are output data of the present *DOE-2* program and therefore also known.

Comparison with measurements

The model has been compared with the measured data sets used in the validation efforts within IEA-ECB Annex 21 [2] and with measurements from the Pala test case [3].





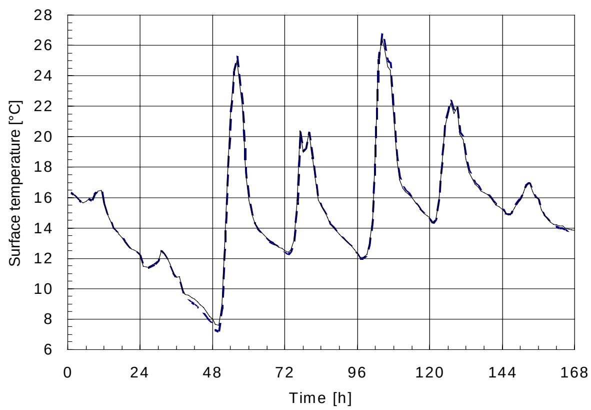
___DOE-2.1E Simulation
- - -IEA Measurements

Fig. 3 *Inside surface temperature of the ceiling.*

Fig 4. *Inside surface temperature of the exterior wall.*

Fig. 3 and 4 show the good agreement between the measurements and the simulation.

Additional comparisons have been made with a window model developed for the building simulation program *TRNSYS* [4]. The calculated window surface temperature for a Window type 4651 has been compared with the result of the new surface temperature routine in *DOE-2.1E*. The comparison shows an excellent agreement (Fig. 5).



___DOE-2.1E Simulation -- TRNSYS Type 97 with DOE-2.1E window model

Fig. 5 *Window inside surface temperature.*

Additional Keywords

<u>BUILDING-LOCATION</u>

SURF-TEMP-CALC Defines whether the calculation of inside surface temperatures is performed or not. The allowable code-words are YES and NO (the default).

<u>WALL-LEVEL KEYWORD</u>

The surface temperature calculation is performed for EXTERIOR-WALLs, ROOFs, WINDOWs, DOORs, UNDERGROUND-WALLs, UNDERGROUND-FLOORs and INTERIOR-WALLs. However, for INTERIOR-WALLs it is not performed for type INTERNAL or AIR.

INSIDE-SURF-TEMP Defines whether the calculated inside surface temperature for the wall is written to a separate output file or not. The allowable code-words are YES and NO (the default).

The output data are written to the file fort.16 in UNIX and for016.dat in VAX/VMS with the following format:

```
ROOM  S-TR  S-TR        ROOM  WIN-  WIN-        ROOM  S-TR  S-TR  ROOM
       -1    -C45  -C45        -1     1     1          -1    -C02  -C02  -2
521 1  27.3  27.0  20.2  21.7  27.3  22.8 -17.8  21.7  27.3  27.0  21.4  21.0
521 2  26.7  26.4  20.2  21.7  26.7  22.6 -17.8  21.7  26.7  26.4  21.4  21.0

 (1)    (2)   (3)   (4)   (5)   (2)   (6)  (7)    (5)   (2)   (3)   (8)   (9)
```

1 Date and Time
2 Zone air temperature
3 Wall inside surface temperature
4 Wall outside surface temperature
5 Outside air temperature
6 Window inside surface temperature
7 Window outside surface temperature (not available in the current version; therefore 0°F or -17.8°C)
8 Wall surface temperature in NEXT-TO zone
9 Air temperature in NEXT-TO zone

The new routine calculates the mean radiative temperature for every zone as a sum of the area-weighted surface temperatures and makes it available as an additional zone hourly report variable in SYSTEMS. Also, the operative temperature, defined as the average of the zone air temperature and the mean radiative temperature, is calculated and available as an hourly report variable.

Hourly-Report Variable List SYSTEMS

VARIABLE-TYPE = u-name of ZONE

Variable-List Number	**Variable in FORTRAN Code**	**Description**
91	TMR	Mean radiative temperature
92	TEFF	Operative temperature

List of Symbols

CR	Common ratio	[–]
h	Combined film coefficient (convective and radiative)	$[W/(m^2)K]$
$\dot{q}_{cd}^{(\tau)}$	Wall conduction	$[W/m^2]$
$\dot{q}_{cv}$	Convective heat flux	$[W/m^2]$
$\dot{q}_r$	Radiative heat flux from people, equipment and solar radiation	$[W/m^2]$
$\dot{q}_w$	Radiative heat flux from other surfaces	$[W/m^2]$
T_a	Air temperature	$[K]$
T_s	Surface temperature	$[K]$
τ	Time	$[h]$
$\Delta\tau$	Time step	$[h]$
X', Y', Z'	Surface-to-surface response factors	$[W/(m^2)K]$

References

[1] DOE-2 Engineers Manual, Version 2.1 A, LBNL University of California Berkeley, Nov 1982.

[2] Empirical Validation Data Sets 099 and 110 from EMC Test Room, BRE (Building Research Establishment), IEA Annex 21, March 1992

[3] R. Meldem and F. Winkelmann, Comparison of DOE-2 with Temperature Measurements in the Pala Test Houses, Energy and Buildings 27 (1998) 69-81

[4] R. Weber und M. Koschenz, Description of Type 97 for TRNSYS, Model for the Calculation of Multi-Layer Windows, EMPA Abteilung Haustechnik, Dez. 1995

This page replaces 3.140 of the DOE-2.1E Supplement. The new information is shaded.

SYSTEM-EQUIPMENT DEFAULT CURVES

The default curves for most of the keywords in the SYSTEM-EQUIPMENT command were upgraded in DOE-2.1C in order to more closely resemble equipment now on the market. The table presented on the next two pages replaces Chapter IV, Table 39, of the *DOE-2 Reference Manual (2.1A)*. Also introduced are four new keywords and accompanying default curves for special use in the PSZ system (see p. 3.103, HEAT RECOVERY FROM REFRIGERATED CASE WORK).

The new curves were developed from rated data using various representative equipment specifications found in manufacturers' catalogs.

RESVVT	37,600 Btu/hr cooling, 34,600 Btu/hr heating, 1100 cfm variable speed heat pump
RESYS	36,000 Btu/hr air-cooled condensing unit, rated 3 tons @ ARI, 1200 cfm, 3 row, 13-14 fins per inch (fpi), 4.5 ft/sec (indoor), 20 fpi, 3.5 ft/sec (outdoor)
PTAC	A combination of data from three units, from 6,900 Btu/hr to 11,800 Btu/hr in size
HP	35,000 Btu/hr cooling, 39,000 Btu/hr heating, shr = 0.74, 26,000 Btu/hr sensible, 4.5 GPM 20°ΔT, 4 row, 12 fpi, 500 ft/min
PSZ	360,000 Btu/hr, 30 tons, 2 compressors unloading to 15%
PMZS	3 condenser fans, 3 row, 15 fpi 7 ft/sec (outdoor condenser)
PVAVS	4 row, 15 fpi, 8 ft/sec (indoor evaporator)
Builtup ahu	Tube and fin coil, 6 row, 15 fpi, 600 ft/min, 86°DB/67°WB, 45° entering water, 10°ΔT, 4 ft/sec
TPFC FPFC	4 row, 14 fpi, 600 ft/min, 44° entering water, 12°ΔT, 6 ft/sec

Curve SDL-C18, COOL-EIR-FPLR for packaged units PSZ, PMZS and PVAVS, comes from data in the ICES Report (ANL/CES/TE 78-2). This curve corresponds to Curve 4 on p. 10 of that report. Coefficients for Curves 1 (Hot Gas Bypass), 2 (Back Pressure Valve) and 3 (Suction Valve-Lift Unloading, Single Compressor) from this same report have been added to the program's pre-defined curves. However, they are not used as defaults for any of the equipment but may be specified as alternatives to SDL-C18. The curve numbers are SDL-C117 (Hot Gas Bypass), SDL-C118 (Back Pressure Valve) and SDL-C119 (Suction Valve). See table on next page for coefficients.

The hydronic heat pump curves have been normalized to a water temperature of 70°F. In earlier versions of the code, 60°F was used. This change reflects a change in the ARI reference conditions from ARI 240-75 to ARI 320-76, and to ASHRAE Standard 90A-1980, Table 6.10.

The default curves (SDL-C16, SDL-C-117, SDL-C20) for COOL-EIR-FPLR for cycling AC units have been replaced with new curves. It was felt that the old curves resulted in an over-prediction of energy use at low part loads. The new curves are derived using a linear degradation coefficient method with a degradation coefficient of 0.04. Details are in report LBNL-42175, included herein.

This page replaces 3.141 of the DOE-2.1E Supplement. The revised information is shaded.

TABLE 3.1 SYSTEM-EQUIPMENT Default Curves

Equations are assumed to take the form:

Linear: $z = a + bx$
Bi-Linear: $z = a + bx + dy$
Cubic: $z = a + bx + cx^2 + dx^3$
Quadratic: $z = a + bx + cx^2$
Bi-Quadratic: $z = a + bx + cx^2 + dy + ey^2 + fxy$

Default Curve u-name	Type of Curve	a	b	c	d	e	f	Keyword	Applicable SYSTEM-TYPEs*	Independent Variables*
		- - - Default Curve Coefficients - - -								
SDL-C1	BI-QUAD	0.6003404	0.0022873	-0.0000128	0.0013898	-0.0000806	0.0001412	COOL-CAP-FT	RESYS	WB/EDB
SDL-C2	BI-QUAD	1.1839345	-0.0081087	0.0002110	-0.0061425	0.0000016	-0.0000030	COOL-CAP-FT	PTAC	WB/EDB
SDL-C3	BI-QUAD	0.8740302	-0.0011416	0.0001711	-0.0029570	0.0000102	-0.0000592	COOL-CAP-FT	PSZ, PMZS, PVAVS	WB/EDB
SDL-C4	BI-QUAD	-0.2938200	0.0222213	0.00006988	0.0040928	-0.00000226	-0.00013774	COOL-CAP-FT	RESVVT	WB/EDB
SDL-C5	BI-QUAD	-0.2780377	0.0248307	-0.0000095	-0.0032731	0.0000070	-0.0000272	COOL-CAP-FT	HP	WB/WT
SDL-C6	BI-QUAD	0.9452633	-0.0094199	0.0002270	0.0004805	-0.0000045	-0.0000599	COOL-CAP-FT	WTR-CC	WB/WT
SDL-C7	BI-QUAD	2.5882585	-0.2305879	0.0038359	0.1025812	0.0005984	-0.0028721	COOL-CAP-FT	SZRH, MZS, DDS, SZCI, TPIU, FPIU, VAVS, RHFS, CBVAV, PIU	WB/DB
SDL-C8	BI-QUAD	0.8740302	-0.0011416	0.0001711	-0.0029570	0.0000102	-0.0000592	COOL-CAP-FT	PVVT	WB/EDB
SDL-C9	BI-LINEAR	1.0976758	0.0106662	0.0000000	-0.0085506	0.0000000	0.0000000	COOL-CAP-FT	GHP	WB/EDB
SDL-C10	BI-QUAD	0.5038866	-0.0869176	0.0016847	0.0336304	0.0002478	-0.0010297	COOL-CAP-FT	TPFC, FPFC	WB/DB
SDL-C11	BI-QUAD	-0.9617787	0.0481775	-0.0002311	0.0032439	0.0001488	-0.0002952	COOL-EIR-FT	RESYS	WB/EDB
SDL-C12	BI-QUAD	-0.6550461	0.0388910	-0.0001925	0.0013046	0.0001352	-0.0002247	COOL-EIR-FT	PTAC	WB/EDB
SDL-C13	BI-QUAD	-1.0639310	0.0306584	-0.0001269	0.0154213	0.0000497	-0.0002096	COOL-EIR-FT	PSZ, PMZS, PVAVS	WB/EDB
SDL-C14	BI-QUAD	-1.8394760	0.0751363	-0.0005686	0.0047090	0.0000901	-0.0001218	COOL-EIR-FT	WTR-CC	WB/EDB
SDL-C15	BI-QUAD	2.0280385	-0.0423091	0.0003054	0.0149672	0.0000244	-0.0001640	COOL-EIR-FT	HP	WB/WT
SDL-C16	CUBIC	.00000273404	1.05259	-.0552087	.00262236	0.0000000	0.0000000	COOL-EIR-FPLR	RESYS	PLR
SDL-C17	CUBIC	.00000273404	1.05259	-.0552087	.00262236	0.0000000	0.0000000	COOL-EIR-FPLR	PTAC	PLR
SDL-C18	CUBIC	0.2012301	-0.0312175	1.9504979	-1.1205105	0.0000000	0.0000000	COOL-EIR-FPLR	PSZ, PMZS, PVAVS	PLR
SDL-C19	CUBIC	0.2012301	-0.0312175	1.9504979	-1.1205105	0.0000000	0.0000000	COOL-EIR-FPLR	WTR-CC	PLR
SDL-C20	CUBIC	.00000273404	1.05259	-.0552087	.00262236	0.0000000	0.0000000	COOL-EIR-FPLR	HP	PLR
SDL-C21	BI-QUAD	6.5275698	-0.1261375	0.0005688	0.0090757	-0.0000483	-0.0000088	COOL-SH-FT	RESYS	WB/EDB
SDL-C22	BI-QUAD	6.3112707	-0.1129951	0.0004334	0.0037738	-0.0000499	0.0000637	COOL-SH-FT	PTAC	WB/EDB
SDL-C23	BI-QUAD	4.8352962	-0.0575307	0.0000616	-0.0052683	-0.0000032	0.0000337	COOL-SH-FT	PSZ, PMZS, PVAVS	WB/EDB

***See definitions at end of table**

This page replaces 3.140 of the DOE-2.1E Supplement. The new information is shaded.
This report (LBNL-42175) may be added to the section SYSTEM-EQUIPMENT Default Curves.

RESIDENTIAL EQUIPMENT PART LOAD CURVES FOR USE IN DOE-2

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This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State and Community Programs, Office of Building Systems of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Residential Equipment Part Load Curves for Use in DOE-2

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February 1999

Overview
DOE-2 (DOE2 90) includes several correlation curves that predict the energy use of systems under part load conditions. DOE-2 simulates systems on an hour-by-hour basis, so the correlations are intended to predict part load energy use (and efficiency) as a function of the part load ratio (PLR) for each hour, where

$$PLR = \frac{HourlyLoad}{AvailableCapacity} \qquad (1)$$

Generally residential and small commercial HVAC equipment meets the load at off-design conditions by cycling on and off. Therefore, the part load correlations must predict the degradation due to this on and off operation over an hourly interval.

Default DOE-2 Curves
The DOE-2 default curves (DOE2 93) predict the normalized change in the Energy Input Ratio (EIR), which is the inverse of COP, as a function of PLR. It is often more convenient to express part load effects in terms of degradation of efficiency under part load. NIST (PARK 77) typically referred to the normalized efficiency degradation as the part load factor, or PLF

$$PLF = \frac{PartLoadEfficiency}{SteadyStateEfficiency} \quad . \qquad (2)$$

The DOE-2 curves for EIR were rearranged to find PLF

$$PLF = \frac{PLR}{EIR(PLR)} \quad . \qquad (3)$$

Figure 1 shows the DOE-2 default curves for part load performance of various types of equipment. Table 1 lists the SYSTEMS and PLANT equipment that use these curves. Due to the form of the equation, all five basic curves show following behavior:

- the part load efficiency goes to zero at as PLR approaches zero,
- the slope of the curves is a strongly a function of loading (i.e., PLR).

The residential cooling curve shows the most part load degradation, followed by the boiler and heat pump heating curves. The furnace and PSZ cooling curves show the least amount of part load degradation.

Table 1: Default Part Load Curves in DOE-2

Description	Curve Name	Curve No	DOE-2 Systems
Residential Cooling	COOL-EIR-FPLR	16,17,20	RESYS,PTAC,HP
Commercial Cooling	COOL-EIR-FPLR	18 128	PSZ,PMZS,PVAVS PVVT
HP Heating	HEAT-EIR-FPLR	61,62,65, 75,116	RESYS, PSZ, PTAC, PVAVS, HP, WTR-CC, PVVT
Furnace	FURNACE-HIR-FPLR	111	any fuel-fired furnace
Boiler	BOILER-HIR-FPLR	BLRHIR2	HP (WLHP system) HW and Steam Boiler Plants

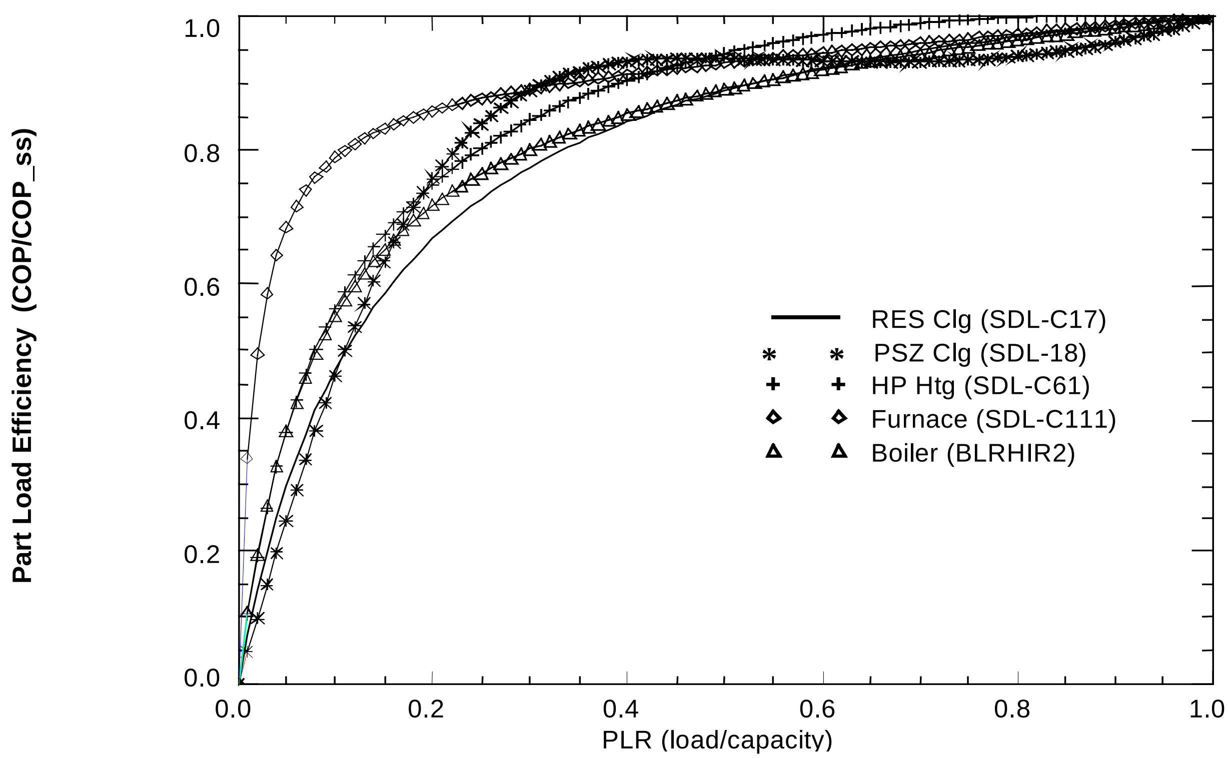

Figure 3: Default Curves from DOE-2

Part Load Degradation for Cycling Equipment

The part load performance of cycling HVAC systems depends on:

1. **the response of the system at startup (usually defined by a time constant or dead time),**
2. **the cycling rate of the equipment (usually defined by thermostat characteristics and building thermal mass).**

Parken and his co-workers at NIST (PARK 85) were the first recognize that these two factors could be combined to form a part load correlation. They used this concept to develop the degradation coefficient (C_d) used in the SEER rating procedure to predict part load effects. The concept was verified with both laboratory and field data.

Henderson and Rengarajan (HEND 96) summarize the equations necessary to calculate the theoretical part load efficiency curve. Figure 2 shows that theoretical function closely matches by the linear C_d method proposed by Parken and used in the SEER rating procedure (DOE 79). The default value of C_d in the SEER rating procedure is 0.25. This value corresponds to time constant (tau) of 76 seconds for the air conditioner at startup, and a maximum cycling rate (N_{max}) of 3.125 cycles per hour.

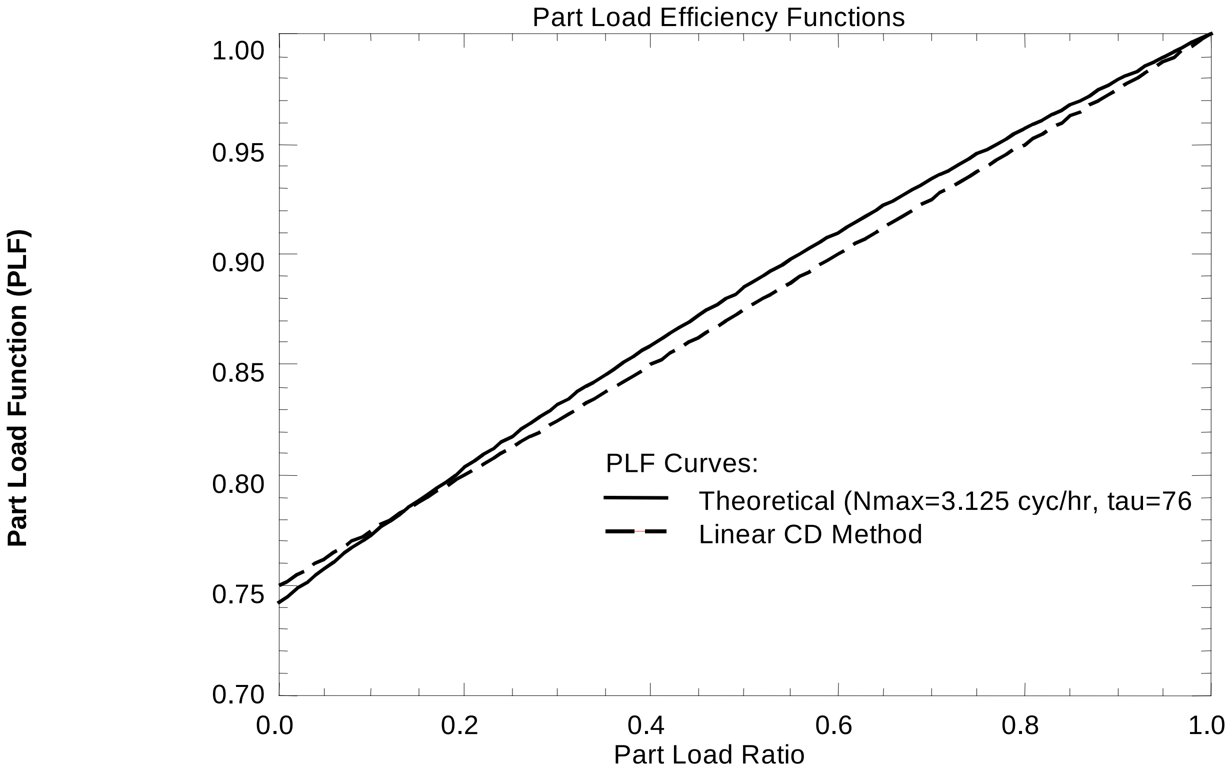

Figure 4: Theoretical and Linear Part Load Functions Based on Parken et al (PARK 1997)

Modern air conditioner and heat pump systems typically have time constant of 40 to 60 seconds. As a result, values of C_d measured for typical systems tested according to the SEER procedure (DOE 79, ASH 96) are in the range of 0.10 to 0.2. Thermostat cycling rates are also generally lower than the default value of 3.125 assumed in the rating procedure. An average cycling rate of 30 Florida homes was found to be 2.5 cycles per hour (HEND 1991). This further reduces the effective value of C_d

Converting the C_d Method into DOE-2/EIR Approach

The linear C_d method assumes that PLF is given by

$$PLF = 1 - C_d(1 - PLR) \quad . \qquad (4)$$

By equating equations (3) and (4), we can see that the function for EIR must be of the form

$$EIR = \frac{PLR}{1 - C_d(1 - PLR)} \quad . \qquad (5)$$

In DOE-2, EIR must be a polynomial. If we fit equation (5) to a cubic polynomial we get a very good fit down to very low values of PLR (as low as 0.05). Figure 3 compares the polynominal fit of EIR to the linear part load function with C_d. Table 2 lists the coefficients corresponding to each curve. These user-defined polynominal coefficients can be used to closely mimic the C_d method.

Table 2: Coefficients for EIR to Match The Linear C_d Model

Degradation Coefficient (C_d)	**Coefficients for EIR-FPLR = a + b·PLR + c·PLR² + d·PLR³**			
	a	**b**	**c**	**d**
0.05	2.73404e-006	1.05259	-0.0552087	0.00262236
0.10	1.48147e-005	1.11079	-0.121905	0.0111199
0.15	6.25583e-005	1.17517	-0.201513	0.0263344
0.20	0.000164298	1.24656	-0.296070	0.0494917
0.25	0.000362523	1.32573	-0.407603	0.0818194
0.30	0.000698967	1.41373	-0.538881	0.125027

Should the Part Load Efficiency (PLF) Approach Zero?

The linear C_d method, as well as its theoretical form, both predict that part load efficiency *does not* approach zero at as PLR approaches zero. The part load efficiency is always greater than zero because the equipment is assumed to have a minimum run time that is a function of the maximum cycle rate[1].

A part load method was developed (BONN 80) by assuming that system startup is described by an equivalent delay time (Z_D) instead of a single time constant. Under these assumptions, the part load efficiency still did not approach zero at zero load.

It was shown (BONN 80, MILL 85) that, when off-cycle power consumption is considered, the part load efficiency curve does approach zero. The off-cycle power can be due to crankcase heaters, controls, fans or other factors. If the off-cycle power use is expressed as a fraction of on-cycle power use (pr), then Bonne showed that the adjusted PLF can be calculated as shown below:

$$PLF' = \frac{PLR}{\left(\frac{PLR}{PLF} + (1 - \frac{PLR}{PLF})\, pr\right)} \quad . \qquad (6)$$

Figure 4 shows that the consideration of even small amounts of off-cycle power has a dramatic impact on efficiency at low load conditions. A value of 0.01 for pr corresponds to about 40 Watts of off-cycle power for a typical 3 ton AC system, while 0.03 corresponds to 120 Watts.

---

[1] Henderson et al (1991), Miller and Jaster (1985) and others showed that the minimum on time can be calculated from the maximum cycle rate (N_{max}) by the following equation:

$$t_{ON,\min} = \frac{60}{4N_{\max}}$$

So if N_{max} equals 3.125 cycles/hr, then the minimum run time is 4.8 minutes.

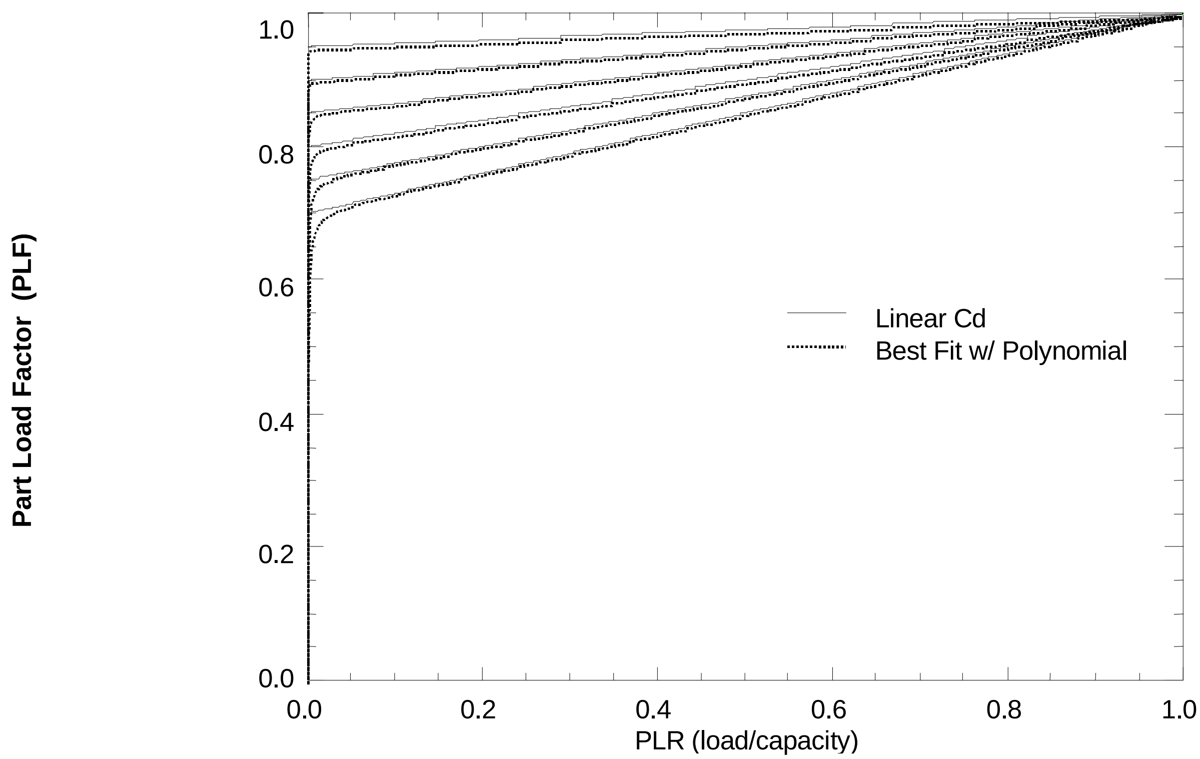

Figure 5: Polynomial fit of EIR Function to Linear C_d Method

Recommended Curves - Residential AC/HP Cooling

Figure 5 shows the range of part load performance that might be expected for a residential cooling system. Table 3 lists the corresponding EIR coefficients. The default RESYS curve is also shown on the plot for reference.

Table 3: Coefficients for EIR to For "Typical AC"

	Coefficients for EIR-FPLR = a + b·PLR + c·PLR^2 + d·PLR^3			
	a	**b**	**c**	**d**
"Typical AC" N_{max}=2.5, tau=60, pr=0.01	0.0101858	1.18131	-0.246748	0.0555745
"Good AC" N_{max}=2.5, tau=60, pr=0.01	0.00988125	1.08033	-0.105267	0.0151403
"Poor AC" N_{max}=3, tau=60, pr=0.03	0.0300924	1.20211	-0.311465	0.0798283

The "Typical AC" is assumed to have a time constant of 60 seconds at startup, which is typical of values reported in the literature and summarized by Henderson (HEND 92). These values ranged from 30 to 80 seconds. The "Good AC" might be representative of a system with a liquid line solenoid or other means of off-cycle refrigerant control and is assumed to have a shorter time constant of 30 seconds.

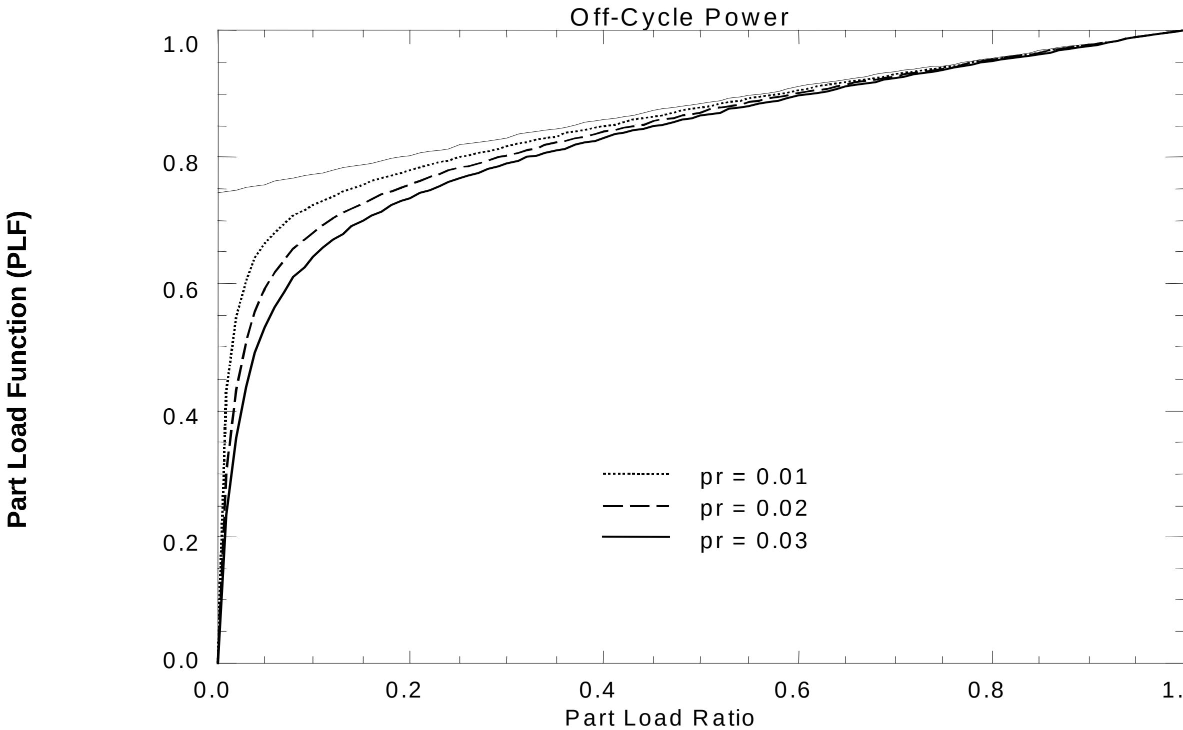

Figure 6: The Impact of Off-Cycle Power on Part Load Efficiency

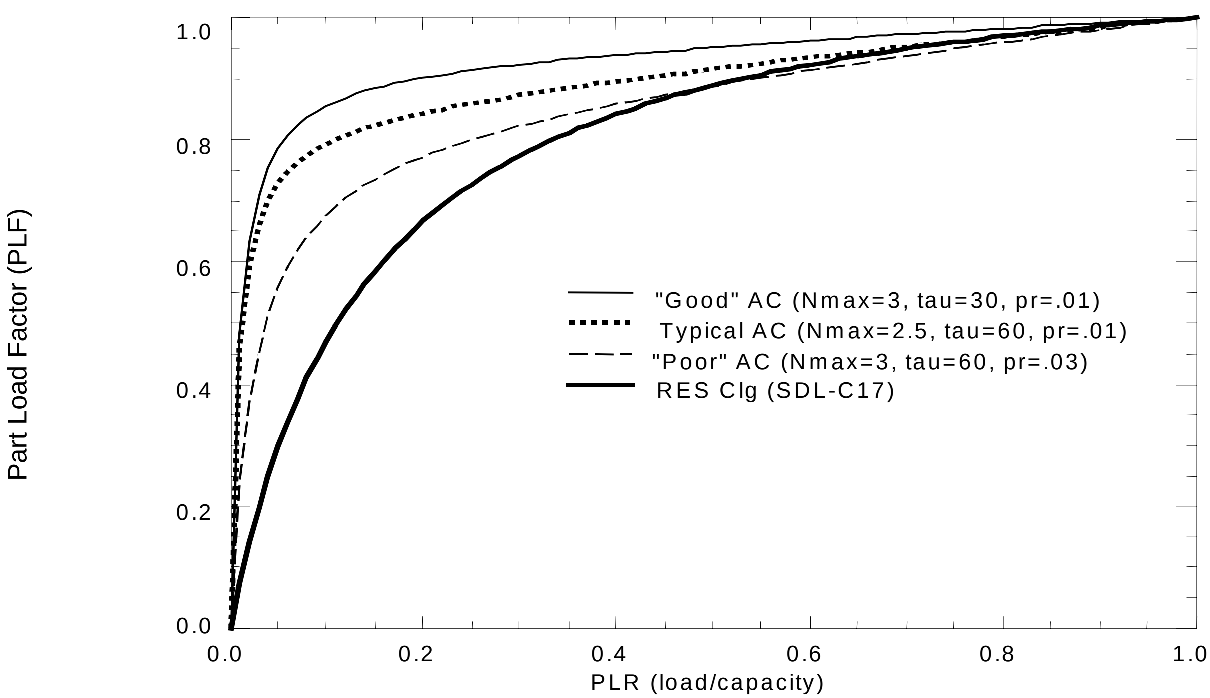

Figure 7: Recommended Parameters for a Typical AC System Compared to Default DOE-2 Curves

The maximum thermostat cycling rate is assumed to be 2.5 cycles per hour for the "Typical AC" – the average measured at 30 Florida homes (HEND 91). By comparison measured values of 1.5 to 3 cycles per hour and 3 was recommended as the "worst case" (MILL 85). Parken (PARK 85) measured values of 1.6, 2.0, and 2.3 cycles/hr in the cooling mode at three test homes. Therefore, the "Poor AC" is expected to have a cycling rate of 3 cycle per hour.

The off-cycle power use is expected to be 1% (0.01), or about 40 Watts with a 3 ton unit for the "Typical AC." This is close to the assumed value of 1.5% (BONN 80). The "Poor AC" is assumed to be 3% (0.03), or 120 Watts for a 3 ton unit.

There is not expected to be much difference between new and existing systems. Most research into part load issues was conducted in the 1970's and 1980's, though work at FSEC and other institutions seems to confirm these earlier findings. While the steady state performance of residential AC and HP systems has improved substantially over the last 10 to 15 years, there is little evidence that part load issues have changed for cycling equipment. The transient response at startup is still expected to be similar, with the exception of systems with liquid line solenoid valves or totally closeable electronic expansion valves which are expected to respond faster since refrigerant is trapped in the condenser. Also, thermostat manufacturers still design for maximum cycling rates of 2 to 3 cycles per hour.

Recommended Curves - Residential HP Heating

The part load, cyclic performance described above for cooling should be fundamentally the same for a residential heat pump in heating[2]. (MILL 85) and (BONN 80) both showed that the transient response is similar for heating and cooling. (PARK 77) showed almost identical part load curves for heating and cooling. Field data (MILL 85) also showed similar thermostat cycling rates for heating and cooling. Therefore, we recommend that the cooling curves in Table 2 and Figure 5 also be used for an air-source heat pump in the heating mode.

Recommended Curves – Residential Furnaces and Boilers

The part load performance of residential furnaces and boilers is primarily driven by flue and stack losses. These losses vary with loading because the heat escapes from the furnace flue when the burner is off. Infiltration losses from the house are also caused by the stack. Work at NBS (CHI 78, KELL 78) formed the basis for the AFUE rating procedures developed by The U.S. Department of Energy (DOE 90). U. Bonne at Honeywell performed part of the testing and analysis. The AFUE procedure is also described in ASHRAE Standard 103-1993.

The work associated with the AFUE test and rating procedure does not explicitly give a part load curve. Their initial work showed that they could "skip" that step and directly calculate a seasonal average value. It appears that they did not identify any transient combustion effects -- all part load issues are related to infiltration and stack losses during the off-cycle.

The only part load curve we found in the literature (BONN 85) was a paper to assess the efficacy of cycling controls that were proposed as a means of efficiency improvement in the mid-1980s. A detailed model, HFLAME, was used to assess impact of increased cycle rates on efficiency. Bonne's work is interesting because it shows part load efficiency of furnaces/boilers can increase slightly at part load conditions. This effect appears to be due to the relatively oversized HX at part load (much as in a variable-speed compressor system). This is possible because there are apparently no transient losses in combustion process.

[2] However, the need for defrost, which depends on the ambient conditions, is a much more complex phenomenon and is not addressed in this report.

Figure 6 shows the part load curves (BONN 85) for both atmospheric combustion systems (which are no longer widely sold) as well as for induced draft (i.e., power burner) systems. These curves assume a standing plot. If an intermittent ignition system is used then the part load curves would not approach zero (for the same reasons discussed above for AC systems. Table 4 lists the HIR coefficients that fit the part load curves.

Table 4: Coefficients for HIR for "Furnace/Boiler"

Furnace/BoilerType	Coefficients for HIR-FPLR = a + b·PLR + c·PLR^2 + d·PLR^3			
	a	b	c	d
Atmospheric N_{max}=6, standing pilot, no flue damper	0.011771251	0.98061775	0.11783017	-0.11032275
Induced Draft N_{max}=6, standing pilot, 50% flow at off-cycle	0.0080472574	0.87564457	0.29249943	-0.17624156

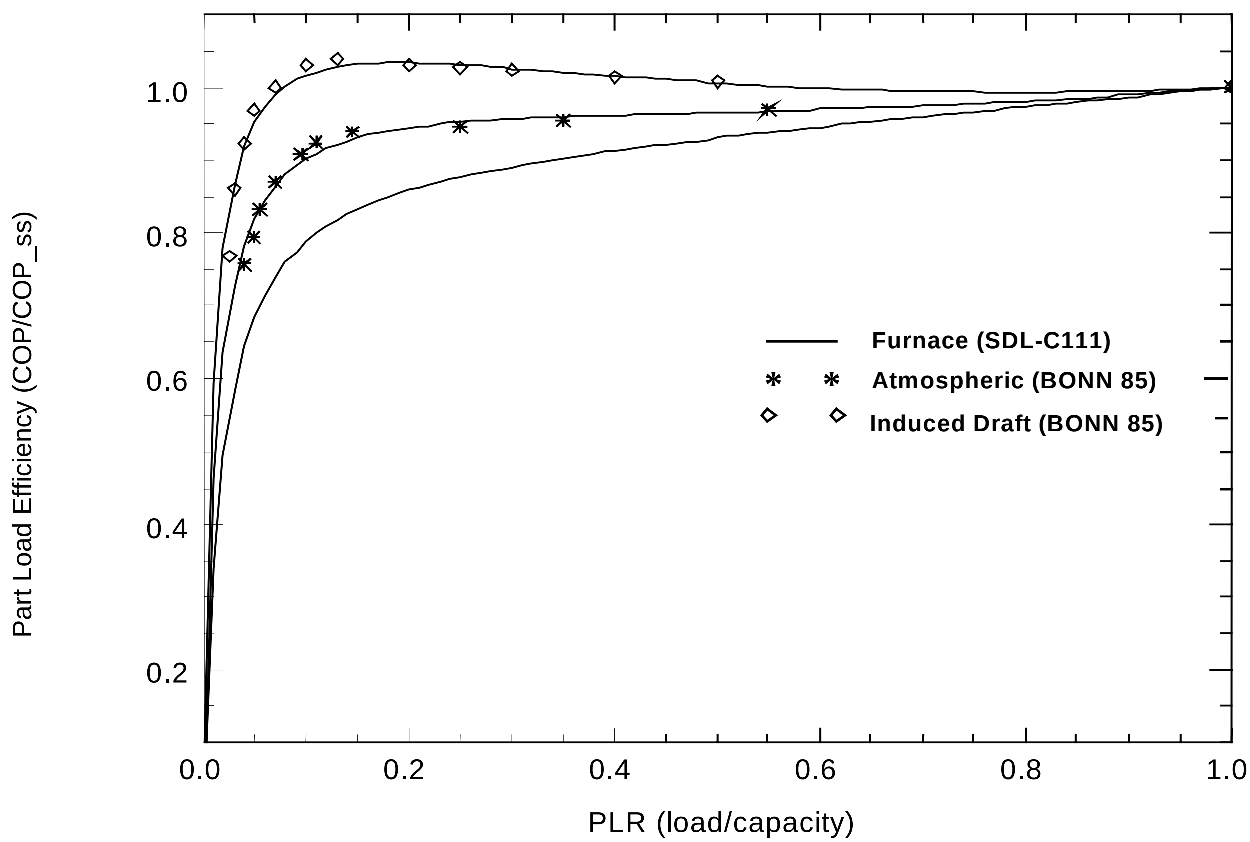

Figure 8: Recommended Curves for Furnaces and Boilers

All this implies that sealed combustion systems that are isolated from the building should have little to no part load degradation, since they eliminate the stack and flue losses. There may even be a slight increase in efficiency as part load, as shown in Figure 6.

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This description of the Cooled Beam System type should be added to the DOE-2.1E Supplement after p. 3.151.

System Type = COOLBEAM

Mixed Air-Hydronic System

The Air System

The Cooled Beam system is a mixed air-hydronic system. A central, single-duct forced-air system supplies conditioned ventilation air to the zones. Sensible cooling is done by chilled water circulating through ceiling-mounted cooled beam units. Heating is accomplished with hot water radiators. Thermodynamically, the cooled beam system resembles the four-pipe induction unit.

The central air system contains the equipment needed to deliver a fixed air flow at a specified temperature; generally, there is a constant volume fan, a chilled water cooling coil, and a hot water heating coil. There is no capability for variable volume operation with this system. The supply air temperature set point is specified by COOL-SET-T (COOL-CONTROL=CONSTANT, the default), or by a COOL-SET-SCH (COOL-CONTROL=SCHEDULED) or COOL-RESET-SCH (COOL-CONTROL=RESET). COOL-CONTROL=WARMEST should not be used with this system since the supply air is not the primary source of cooling.

Any moisture removal or addition must be done by the central air system. MAX-HUMIDITY and MIN-HUMIDITY limits can be set and the air system will add (with a humidifier) or remove (at the cooling coil) moisture to satisfy these limits. However this system is generally run without explicit moisture control.

By default the system air flow is set to meet the ventilation requirement, creating a 100 percent outside air system. However, you can force the use of recirculated air by setting the SUPPLY-FLOW higher than the ventilation requirement. Since this is usually a 100 percent outside air system, an air side economizer is not usually used. Thus, OA-CONTROL defaults to FIXED.

Add-on desiccant and evaporative cooler units would be unusual but are permitted. Heat recovery (RECOVERY-EFF) would be normal with this system.

The Hydronic System

There are separate chilled water and hot water loops. The chilled water circulates through ceiling mounted chilled beam units. The entering water temperature is fairly high (typically 59°F) and the temperature increase modest (4°F).

The cooled beam units are either active or passive.

- In the **active** unit, primary air is supplied through the beam, inducing some secondary zone air into contact with the coil. This unit acts as an active convector.
- The **passive** unit is simply a passive, finned convector; primary air is supplied through a normal diffuser.

In both cases most cooling occurs convectively, but some cooling occurs by radiant exchange between the room surfaces and the cooled beam units. DOE-2 assumes that the cooling is 100 percent convective. The units are controlled by varying the water flow rate.

The hot water loop supplies hot water radiators in each zone. In DOE-2 these are specified in the BASEBOARD keywords in the ZONE and ZONE-EQUIPMENT commands. Usually BASEBOARD-CTRL should be THERMOSTATIC. A BASEBOARD-RATING should be given for each zone, since the baseboards (radiators) are not sized automatically.

The cooled beam units are sized automatically based on the space loads minus whatever cooling is done by the primary air. Generally you should not have to specify anything about the cooled beam unit besides BEAM-TYPE = ACTIVE (the default) or PASSIVE.

Humidity and Condensation

One concern with the cooled beam units is condensation. Generally the units are not used in climates or spaces where high humidity can be expected. A control algorithm has been implemented in the units and in the simulation that can prevent condensation. The simulation calculates humidity in each zone. When the highest zone humidity is such that condensation will occur at the entering water temperature, the entering water temperature is raised sufficiently to prevent condensation. Thus, potential condensation causes a rise in supply water temperature and a consequent lowering of the cooled beam cooling capacity.

Generally, the HVAC system simulations in DOE-2 only calculate humidity at the system level; namely in the return air stream. The cooled beam system is the first system in DOE-2 to calculate zone humidity levels. For the cooled beam system the zone humidity ratio is an hourly report variable. It is variable number 93 at the zone level in Systems.

Under the SYSTEM-EQUIPMENT Command:

New keywords, specific to the cooled beam system, have been added to the command SYSTEM-EQUIPMENT. The keywords are used to model the cooled beam performance with the following equations.

Beam cooling capacity per unit length is given by $A \bullet K \bullet \Delta T$ (W/m)

where $K = \alpha \bullet \Delta T^{n_1} \bullet (\nu\rho)^{n_2} \bullet \omega^{n_3}$ $(W/(m^2K))$

and $\nu\rho = (q_{ind} / \alpha_0) \bullet \rho_{air}$ $(kg/(m^2s))$

and $q_{ind} = K_1 \bullet \Delta T^n + K_{in} \bullet q_{sup}$ $(m^3/(sim))$

Symbol	Definition	Symbol	Keyword
ΔT	Temperature difference between the room air and the average water temperature.	A	BEAM-AREA
K	Coil heat transfer coefficient.	α	BEAM-A
$\nu\rho$	Mass flow rate of air through the coil.	n_1	BEAM-N1
ω	Water flow velocity (m/s).	n_2	BEAM-N2
q_{ind}	Induced air flow rate per beam length.	n_3	BEAM-N3
q_{sup}	Supply air flow rate through the active beam (m^3/s).	α_0	BEAM-A0
		K_1	BEAM-K1
		n	BEAM-N
		K_{in}	BEAM-KIN

The keywords BEAM-AREA, BEAM-A, BEAM-N1, BEAM-N2, BEAM-N3, BEAM-A0, BEAM-K1, BEAM-N and BEAM-KIN will vary for different cooled beam products. These keywords should be allowed to default or new values should be obtained from the manufacturer.

Except for BEAM-WATER-T-IN and BEAM-WATER-T-OUT the keywords are unit-less or always in metric.

SYSTEM-EQUIPMENT

BEAM-TYPE	Takes code-words ACTIVE (the default) and PASSIVE that denote the type of beam.
BEAM-WATER-T-IN	Water inlet temperature; default is 59F/15C.
BEAM-WATER-T-OUT	Water outlet temperature; default is 62.6F/17C.
BEAM-A	Coefficient; default is 15.3.
BEAM-A0	Free area of coil in plan view (for the air flow) (m^2/m); default is 171.
BEAM-AREA	Coil surface area per coil length (m^2/m); default is 5.422.
BEAM-D	Water pipe inside diameter (m); default is 0.0145.
BEAM-KIN	Coefficient of induction; default is 2.0.
BEAM-K1	Coefficient; default is 0.005.
BEAM-N	Coefficient; default is 0.4.
BEAM-N1	Coefficient; default is 0.0.
BEAM-N2	Coefficient; default is 0.84.
BEAM-N3	Coefficient; default is 0.12

Input template for cooled beam system (with some typical values)

Under SYSTEM or SYSTEM subcommands

SYSTEM-TYPE	=	COOLBEAM
FAN-SCHEDULE	=	U-name *of schedule for supply fan on/off*
COOLING-SCHEDULE	=	U-name *of schedule for cooling on/off*
HEATING-SCHEDULE	=	U-name *of schedule for heating on/off*
MIN-SUPPLY-T	=	55 *used to size cooling coil*
HEAT-SET-T	=	65 *used to size heating coil*
COOL-CONTROL	=	RESET
COOL-RESET-SCH	=	U-name *of a reset temperature schedule that determines the supply air set point*
SUPPLY-STATIC	=	5.5 *inches of total system static pressure*
SUPPLY-EFF	=	.55 *includes fan, drive and motor*
BEAM-TYPE	=	ACTIVE *selects beam type; this is the default so this input is not needed*
BEAM-WATER-T-IN	=	59 *inlet beam design water temperature*
BEAM-WATER-T-OUT	=	63 *outlet beam design water temperature*

Under ZONE or ZONE subcommands

DESIGN-HEAT-T	=	70
DESIGN-COOL-T	=	76
HEAT-TEMP-SCH	=	U-name *of scheduled thermostat heating set point*
COOL-TEMP-SCH	=	U-name *of scheduled thermostat cooling set point*
OA-FLOW/PER	=	20
BASEBOARD-CTRL	=	THERMOSTATIC *thermostatic baseboards simulate hot water radiators; they are the sole heating source for the zone*
BASEBOARD-RATING	=	-40000 *the baseboard size must be input; it is not sized automatically*

Cool Beam System -- Output Reports

The results of the cooled beam design and sizing calculations are displayed in an addendum to report SV-A. For each zone the number of beams, the beam length, and the maximum water flow rate are displayed. For the system, the design inlet and outlet water temperatures are shown.

In the summary reports, Report SS-B shows the monthly and annual cooling done by the cooled beam units in the column labeled *Zone Cooling*. The total system cooling – cooling by both the cooled beams and the air system – is shown in Report SS-A.

Four hourly report variables have been added for the cooled beam system: the beam cooling capacity for the zone, the beam inlet temperature, the beam outlet temperature, and the beam water flow rate. These are variables 96, 97, 98, and 99, respectively, at the zone level in Systems. In addition, the existing hourly report variable ZQC is used to report the hourly cooling performed by the beams in each zone. ZQC is variable number 33 at the zone level. It will be labeled “zone cooling.” At the system level, variable 8, QCZ, will contain the total system-wide cooling done by all the cooled beam units.

Example COOLBEAM Output – SV-A

```
 REPORT- SV-A  SYSTEM DESIGN PARAMETERS                      SYST-1                WEATHER FILE- Chicago IL TMY2
-----------------------------------------------------------------------------------------------------------------
 SYSTEM           SYSTEM          ALTITUDE     FLOOR AREA     MAX
  NAME             TYPE          MULTIPLIER     (SQFT )      PEOPLE

SYST-1           CoolBeam           1.020        5000.0       52.

 SUPPLY                          RETURN                         OUTSIDE  COOLING               HEATING   COOLING   HEATING
  FAN     ELEC     DELTA-T   FAN     ELEC    DELTA-T         AIR   CAPACITY  SENSIBLE  CAPACITY      EIR       EIR
 (CFM )   (KW)     (F)      (CFM )  (KW)    (F)            RATIO  (KBTU/HR)  (SHR)    (KBTU/HR) (BTU/BTU) (BTU/BTU)

  1061.  1.221    3.6        0.     0.000   0.0           1.000   33.849     0.737   -19.224     0.00       0.37

          SUPPLY   EXHAUST     MINIMUM     OUTSIDE   COOLING    SENS  EXTRACTION    HEATING   ADDTN
 ZONE       FLOW      FLOW   FAN    FLOW   AIR FLOW  CAPACITY   IBLE        RATE   CAPACITY   RATE       MULTI-
 NAME      (CFM )    (CFM )  (KW)  RATIO     (CFM )  (KBTU/HR)  (SHR)   (KBTU/HR)  (KBTU/HR) (KBTU/HR)  PLIER
SPACE5-1    408.        0.  0.000  1.000       408.      20.00   1.00    29.32          0.00   -40.00    1.0
SPACE1-1    224.        0.  0.000  1.000       224.      28.59   1.00    33.71          0.00   -40.00    1.0
SPACE2-1    102.        0.  0.000  1.000       102.      10.69   1.00    13.02          0.00   -15.00    1.0
SPACE3-1    224.        0.  0.000  1.000       224.      14.83   1.00    19.95          0.00   -35.00    1.0
SPACE4-1    102.        0.  0.000  1.000       102.       9.63   1.00    11.96          0.00   -15.00    1.0
PLENUM-1      0.        0.  0.000  0.000         0.       0.00   0.00     0.00          0.00     0.00    1.0

COOLBEAM DESIGN PARAMETERS

Beam Type: ACTIVE

Inlet Water Temperature = 59.0 (F)    Outlet Water Temperature = 62.6 (F)

                          NUMBER                BEAM                 MAX
         ZONE                 OF              LENGTH                FLOW
         NAME              BEAMS                (FT)        (GAL/MIN    )

SPACE5-1                      11              15.091                 1.0
SPACE1-1                      15              20.677                 1.1
SPACE2-1                       6              18.865                 1.0
SPACE3-1                       8              17.325                 1.0
SPACE4-1                       5              19.729                 1.1
PLENUM-1                       0               0.000                 0.0
```

Example COOLBEAM Output – SS-B

REPORT- SS-B SYSTEM MONTHLY LOADS SUMMARY FOR SYST-1 WEATHER FILE- Chicago IL TMY2

	Z O N E C O O L I N G		Z O N E H E A T I N G		B A S E B O A R D S		PREHEAT OR FURN FAN ELEC	
MONTH	CCOOLING BY ZONE COILS OR NAT VENT (MBTU)	MAX COOLING BY ZONE COILS OR NATURAL VENTILATION (KBTU/HR)	HEATING BY ZONE COILS OR FURNACE (MBTU)	MAXIMUM HEATING BY ZONE COILS OR FURNACE (KBTU/HR)	BASEBOARD HEATING ENER (MBTU)	MAXIMUM BASEBOARD HEATING ENERGY (KBTU/HR)	PREHEAT COIL ENERGY OR ELEC ENERGY FOR FURN FAN FAN (MBTU)	MAX PRE- HEAT COIL OR ELEC FOR FURN FAN (KBTU/HR)
JAN	0.00000	0.000	0.00000	0.000	-15.34915	-145.000	-5.47788	-64.600
FEB	0.00000	0.000	0.00000	0.000	-11.15917	-145.000	-3.92870	-47.215
MAR	0.00302	1.699	0.00000	0.000	-8.29606	-145.000	-2.29658	-29.414
APR	0.18343	12.492	0.00000	0.000	-1.27628	-117.742	-0.26831	-15.426
MAY	4.00885	48.438	0.00000	0.000	0.00000	0.000	0.00000	0.000
JUN	8.60135	94.772	0.00000	0.000	0.00000	0.000	0.00000	0.000
JUL	12.46600	105.428	0.00000	0.000	0.00000	0.000	0.00000	0.000
AUG	10.84166	103.677	0.00000	0.000	0.00000	0.000	0.00000	0.000
SEP	7.19111	63.495	0.00000	0.000	0.00000	0.000	0.00000	0.000
OCT	2.18411	38.960	0.00000	0.000	-0.24217	-84.936	-0.08333	-20.348
NOv	0.02146	4.173	0.00000	0.000	-4.71088	-143.771	-1.57615	-25.048
DEC	0.00000	0.000	0.00000	0.000	-13.06173	-145.000	-4.49701	-64.166
0TOTAL	45.501		0.000		-54.095		-18.128	
0MAX		105.428		0.000		-145.000		-64.600

Example COOLBEAM Output – SS-A

REPORT- SS-A SYSTEM MONTHLY LOADS SUMMARY FOR SYST-1 WEATHER FILE- Chicago IL TMY2

	-----------C O O L I N G-----------						-------H E A T I N G-------------------						E L E C T R I C	
MONTH	COOLING ENERGY (MBTU)	TIME OF MAX DY	HR	DRY- BULB TEMP	WET- BULB TEMP	MAXIMUM COOLING LOAD (KBTU/HR)	HEATING ENERGY (MBTU)	TIME OF MAX DY	HR	DRY- BULB TEMP	WET- BULB TEMP	MAXIMUM HEATING LOAD (KBTU/HR)	ELEC- TRICAL ENERGY (KWH	MAX ELEC LOAD (KW)
JAN	0.00552	21	15	54.F	47.F	2.698	-23.531	7	7	-9.F	-10.F	-220.913	3348.	13.221
FEB	0.00140	28	11	53.F	44.F	1.401	-17.397	11	7	5.F	4.F	-203.321	2933.	13.221
MAR	0.08392	14	18	62.F	58.F	14.747	-12.887	4	7	20.F	18.F	-185.471	3238.	13.221
APR	0.97646	3	14	70.F	62.F	26.076	-2.318	22	7	35.F	31.F	-140.009	3273.	13.221
MAY	7.67516	30	17	85.F	72.F	85.206	-0.034	8	9	48.F	41.F	-5.090	3299.	13.221
JUN	14.90615	17	7	74.F	68.F	130.476	0.000					0.000	3075.	13.221
JUL	21.21086	8	7	71.F	68.F	137.339	0.000					0.000	3337.	13.221
AUG	19.32559	5	7	70.F	67.F	138.202	0.000					0.000	3331.	13.221
SEP	12.17852	6	18	78.F	71.F	98.437	-0.004	3	7	49.F	48.F	-3.601	3073.	13.221
OCT	4.30464	4	17	77.F	61.F	64.490	-0.703	21	7	28.F	27.F	-116.606	3298.	13.221
NOV	0.10168	1	15	55.F	49.F	7.701	-8.070	18	7	25.F	24.F	-178.763	2989.	13.221
DEC	0.00183	12	13	53.F	47.F	1.407	-20.077	31	7	-8.F	-9.F	-218.922	3242.	13.221
TOTAL	80.772						-85.021						38434.	
MAX						138.202						-220.913		13.221

Example COOLBEAM Output – Hourly Report

```
 SYSS-REP-1       = HOURLY-REPORT                                                                            PAGE  1 -  1
 ----------------------------------------------------------------------------------------------------------------------------
 MMDDHH  GLOBAL     GLOBAL    SPACE1-1 SPACE1-1   SPACE1-1      SPACE1-1    SPACE1-1    SPACE1-1   SPACE1-1  SPACE1-1 SPACE1-1

         DRY BULB   HUMIDITY  ZONE     THERMOST   EXTRACTN      BASEBRD     ZONE        HUMIDITY   COOLBEAM  CL BEAM  CL BEAM
         TEMP       RATIO     TEMP     SETPOINT   RATE          HTG RATE    COOLING     RATIO      CAPACITY  IN TEMP  OUT TEMP
         F          FRAC.OR   F        F          BTU/HR        BTU/HR      BTU/HR      FRAC.OR    BTU/HR    F        F
                    MULT.                                                               MULT.
         ----( 8)   ----(10)  ----( 6) ----( 7)   ----( 8)      ----(15)    ----(33)    ----(93)   ----(96)  ----(97) ----(98)
  7 8 1     70.0     0.0138     89.1   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
  7 8 2     70.0     0.0130     88.7   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
  7 8 3     71.0     0.0128     88.4   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
  7 8 4     68.0     0.0121     88.0   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
  7 8 5     69.0     0.0125     87.7   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
  7 8 6     71.0     0.0143     78.3     78.0       33983.            0.      28777.     0.0101      44553.     59.0     68.3
  7 8 7     77.0     0.0152     78.1     78.0       23448.            0.      19611.     0.0105      34327.     59.0     66.1
  7 8 8     81.0     0.0159     78.2     78.0       24042.            0.      20565.     0.0123      34184.     59.0     66.1
  7 8 9     85.0     0.0159     78.6     78.0       24093.            0.      20805.     0.0127      26214.     62.8     68.4
  7 810     89.0     0.0150     78.7     78.0       24777.            0.      21563.     0.0128      25067.     63.6     68.5
  7 811     91.0     0.0136     78.8     78.0       25024.            0.      21772.     0.0123      24620.     63.9     68.4
  7 812     91.0     0.0137     78.7     78.0       25629.            0.      22231.     0.0115      26819.     62.8     68.5
  7 813     92.0     0.0143     78.6     78.0       28084.            0.      24704.     0.0121      31149.     60.8     67.3
  7 814     90.0     0.0148     78.8     78.0       28644.            0.      25390.     0.0126      28142.     62.2     67.0
  7 815     93.0     0.0141     79.1     78.0       29009.            0.      25686.     0.0126      25707.     63.5     66.9
  7 816     91.0     0.0137     79.0     78.0       29475.            0.      26133.     0.0126      26252.     63.4     66.8
  7 817     90.0     0.0131     79.0     78.0       29271.            0.      25841.     0.0124      26253.     63.3     66.9
  7 818     89.0     0.0133     85.8   -999.0           0.            0.          0.     0.0007          0.      0.0      0.0
  7 819     86.0     0.0149     86.4   -999.0           0.            0.          0.     0.0001          0.      0.0      0.0
  7 820     82.0     0.0133     86.4   -999.0           0.            0.          0.     0.0001          0.      0.0      0.0
  7 821     81.0     0.0128     86.1   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
  7 822     80.0     0.0130     85.8   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
  7 823     78.0     0.0135     85.6   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
  7 824     78.0     0.0135     85.4   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
0 DAILY SUMMARY (JUL  8)
     MN     68.0     0.0121     78.1   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
     MX     93.0     0.0159     89.1     78.0       33983.            0.      28777.     0.0128      44553.     63.9     68.5
     SM   1963.0     0.3321   1987.3 -11052.0      325479.            0.     283078.     0.1455     353288.    743.3    809.2
     AV     81.8     0.0138     82.8   -460.5       13562.            0.      11795.     0.0061      14720.     31.0     33.7
0 MONTHLY SUMMARY (JUL)
     MN     68.0     0.0121     78.1   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
     MX     93.0     0.0159     89.1     78.0       33983.            0.      28777.     0.0128      44553.     63.9     68.5
     SM   1963.0     0.3321   1987.3 -11052.0      325479.            0.     283078.     0.1455     353288.    743.3    809.2
     AV     81.8     0.0138     82.8   -460.5       13562.            0.      11795.     0.0061      14720.     31.0     33.7
0 YEARLY SUMMARY
     MN     68.0     0.0121     78.1   -999.0           0.            0.          0.     0.0000          0.      0.0      0.0
     MX     93.0     0.0159     89.1     78.0       33983.            0.      28777.     0.0128      44553.     63.9     68.5
     SM   1963.0     0.3321   1987.3 -11052.0      325479.            0.     283078.     0.1455     353288.    743.3    809.2
     AV     81.8     0.0138     82.8   -460.5       13562.            0.      11795.     0.0061      14720.     31.0     33.7
```

Example COOLBEAM Output – Hourly Report

```
 SYSS-REP-1       = HOURLY-REPORT                              PAGE  1 -  2
 -------------------------------------------------------------------------
 MMDDHH    SPACE1-1      SYST-1        SYST-1        SYST-1       SYST-1

           CL BEAM       TOT CLG       TOT ZONE      TOT BSBD     MAX ZON
           WTR FLOW      COIL PWR      CLG PWR       ENERGY       HUM RAT
           GAL/MIN       BTU/HR        BTU/HR        BTU/HR       FRAC.OR
                                                                  MULT.
           ----(99)      ----( 6)      ----( 8)      ----( 9)     ----215-
  7 8 1         0.000            0.            0.            0.      0.0000
  7 8 2         0.000            0.            0.            0.      0.0000
  7 8 3         0.000            0.            0.            0.      0.0000
  7 8 4         0.000            0.            0.            0.      0.0000
  7 8 5         0.000            0.            0.            0.      0.0000
  7 8 6         0.413       137339.       100807.            0.      0.0101
  7 8 7         0.366       119292.        75427.            0.      0.0105
  7 8 8         0.385       126827.        78975.            0.      0.0123
  7 8 9         0.502       121599.        72127.            0.      0.0127
  7 810         0.584       120415.        72348.            0.      0.0128
  7 811         0.639       116363.        72033.            0.      0.0123
  7 812         0.526       121927.        74979.            0.      0.0115
  7 813         0.506       132537.        81778.            0.      0.0121
  7 814         0.708       127205.        77919.            0.      0.0126
  7 815         1.013       124032.        74945.            0.      0.0126
  7 816         1.017       121158.        75699.            0.      0.0126
  7 817         0.971       117889.        75108.            0.      0.0124
  7 818         0.000            0.            0.            0.      0.0007
  7 819         0.000            0.            0.            0.      0.0001
  7 820         0.000            0.            0.            0.      0.0001
  7 821         0.000            0.            0.            0.      0.0000
  7 822         0.000            0.            0.            0.      0.0000
  7 823         0.000            0.            0.            0.      0.0000
  7 824         0.000            0.            0.            0.      0.0000
0 DAILY SUMMARY (JUL  8)
     MN         0.000            0.            0.            0.      0.0000
     MX         1.017       137339.       100807.            0.      0.0128
     SM         7.630      1486585.       932145.            0.      0.1455
     AV         0.318        61941.        38839.            0.      0.0061
0 MONTHLY SUMMARY (JUL)
     MN         0.000            0.            0.            0.      0.0000
     MX         1.017       137339.       100807.            0.      0.0128
     SM         7.630      1486585.       932145.            0.      0.1455
     AV         0.318        61941.        38839.            0.      0.0061
0 YEARLY SUMMARY
     MN         0.000            0.            0.            0.      0.0000
     MX         1.017       137339.       100807.            0.      0.0128
     SM         7.630      1486585.       932145.            0.      0.1455
     AV         0.318        61941.        38839.            0.      0.0061
```

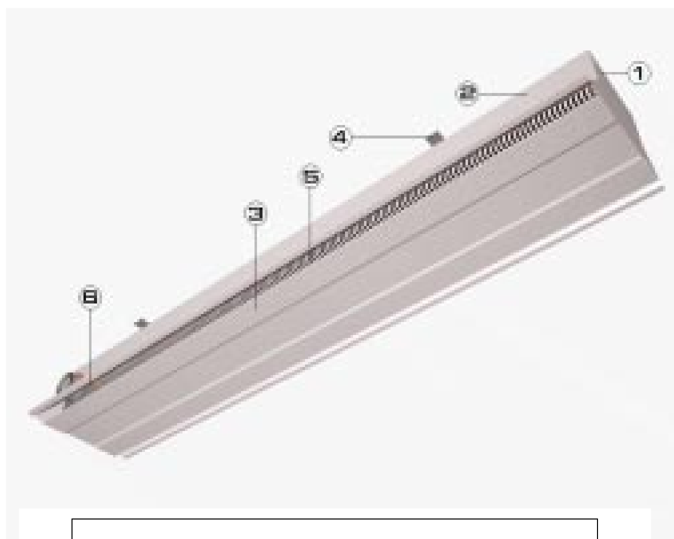
Sample Manufacturer's Data for Active Cool Beam

The CLF ventilated cooled beam is a combined cooling and supply air device incorporating a closed air circulation. It can be installed fully exposed or recessed into the ceiling. The room air enters through a slot on the same side of the device. The cooling power of the device is based on the convective cooling of room air within the heat exchanger.

The device incorporates a casing that serves as a supply air duct. The side panels and bottom plate are made of hot-galvanized steel. The water circuit is made of copper and the heat exchangers are of aluminum. The visible parts of the device have been epoxy-painted white. There are four connection alternatives for the duct and water circuit in both ends of the device (end, left, right and top). The device has a plenum box for the volume control damper. The cooling water circulates through the heat exchangers located inside the device and have connections of Cu 15, and are tested to a pressure of 1.0 MPa. The bottom plate of the device can be detached for installation and cleaning. The diameter of the air duct connection of the device is D125 mm. The width of the device is 595 mm. The total length can be selected 1800 - 3600 in sections of 300 mm. The coil length is 300 mm shorter than the total length.

Supply air enters the beam through the supply air duct where it is directed into the casing. From there it is supplied from below the heat exchangers through the nozzles located on the side of the supply plenum and out through the slot on the bottom of the device into the space. The supply air blown through nozzles induces room air, which flows into the device through the other longitudinal slot.

Cooling is based on the convective cooling of the room air within the heat exchanger. The cooling output of the device is controlled by changing the water mass flow rate.



No.	**NAME**
1	END PLATE
2	SIDE PLATE
3	BOTTOM PLATE
4	CEILING BRACKET
5	HEAT EXCHANGER
6	CASING

The air volume flow rate is determined by measuring the pressure difference from the pressure tubes of the measurement and adjustment section and calculating the corresponding volume flow rate with the correction coefficient. The volume flow rate is adjusted by turning the control spindle of the measurement and adjustment part. The cooling power is controlled by changing the flow rate of the cooling water.

CLF	
Tr [°C]	24.0
Ts [°C]	18.0
qv [dm^3/s]	18.9
Tw1 [°C]	14.0
qmw [kg/s]	0.060
1 [mm]	3600.
Pw [W]	424.
Pa [W]	136.
Pt [W]	559.

Operating Point Calculation

Please replace p. A.18 in the DOE-2.1E Supplement, in Appendix A, Hourly Report Variable List, with this page.

SYSTEMS

VARIABLE-TYPE = u-name of ZONE (continued)

Variable-List Number	Variable in FORTRAN Code	Description
16	QOVER	Amount of extra heat extraction needed to hold the setpoint if load not met (Btu/hr)
17	THZ	Thermostat setpoint for heating (F)
18	TCZ	Thermostat setpoint for cooling (F)
19	ERMAX	Maximum heat extraction rate (meaningful only within the current thermostat band) (Btu/hr)
20	ERMIN	Minimum heat extraction rate (meaningful only within the current thermostat band) (Btu/hr)
21	TRY	Trial zone temperature (if no zone coil activity) (F)
22	FTD	F in temperature variation calculation (subroutine TEMDEV) (Btu/hr)
23	CORINT	A part of the correction in SYSTEMS for the contribution to the zone load due to conduction from adjacent zones (partially calculated in LOADS) (Btu/hr)
24	G0	Air temperature weighting factors (Btu/hr-F)
25	G1	Air temperature weighting factors (Btu/hr-F)
26	G2	Air temperature weighting factors (Btu/hr-F)
27	G3	Air temperature weighting factors (Btu/hr-F)
28	SIGMAG	G0 + G1 + G2 + G3 (Btu/hr-F)
29	TL	Induced air temperature (F) for TPIU, FPIU, SZCI
30	ZQHR	Position of reheat load that would bring the supply temperature to the zone temperature (Btu/hr)
31	TAVE	The average zone air temperature during this hour (F). This is the value used for the energy calculation
32	ZQH	Zone coil heating (Btu/hr)
33	ZQC	Zone coil cooling (Btu/hr)
		For SYSTEM-TYPE=COOLBEAM, reports the hourly cooling performed by the beams in each zone.

Please replace p. A.21 in the DOE-2.1E Supplement, in Appendix A, Hourly Report Variable List, with this page.

SYSTEMS

VARIABLE-TYPE = u-name of ZONE (continued)

Variable-List Number	Variable in FORTRAN Code	Description
Items 65-69 below are for SYSTEM-TYPE=HP only		
65	GPMZ	Flow through unit condenser (gpm)
66	GPMZH	Flow during unit heating (gpm)
67	GPMCZ	Flow during unit cooling (gpm)
68	QHLUPZ	Heat taken from loop (Btu/hr)
69	QCLUPZ	Heat added to loop (Btu/hr)
Items 70-90 unused;		
91	TMR	Mean radiative temperature
92	TEFF	Operative temperature
Items 93-95 unused;		
Items 96-99 are for SYSTEM-TYPE=COOLBEAM only		
96		Beam cooling capacity for the zone (Btu/hr)
97		Beam inlet temperature (°F)
98		Beam outlet temperature (°F)
99		Beam water flow rate (gpm)

Please replace p. A.28 in the DOE-2.1E Supplement, in Appendix A, Hourly Report Variable List, with this page.

SYSTEMS

VARIABLE-TYPE = u-name of SYSTEM (continued)

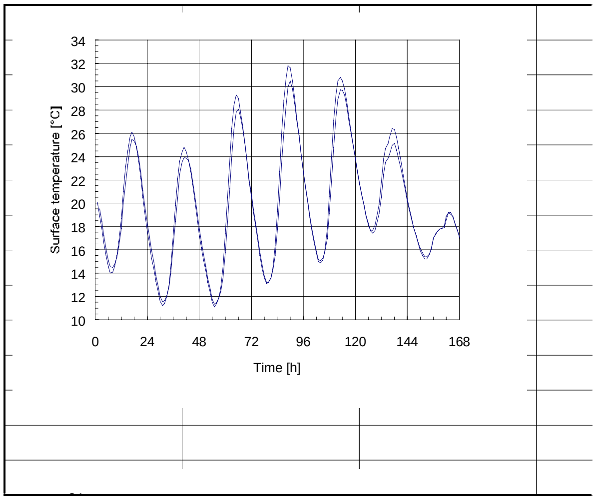
Variable-List Number	Variable in FORTRAN Code	Description
1	TH	Temperature of air leaving heating coil - hot deck temp (F)
2	TC	Temperature of air leaving cooling coil - cold deck temp (F)
3	TM	Temperature of air entering coil (F)
4	TR	Return air temperature on the downstream side of the return fan and plenums (F)
5	QH	Total central heating coil energy input (Btu/hr)
6	QC	Total central cooling coil energy input (Btu/hr)
7	QHZ	Total zone heating energy input (Btu/hr)
8	QCZ	For SYSTEM-TYPE=RESYS, this is the cooling by natural ventilation
		For SYSTEM-TYPE=COOLBEAM, this is the total system-wide cooling done by all the cooled beam units
9	QHB	Total baseboard heating energy input (Btu/hr)
10	QHP	Total preheat coil energy input (Btu/hr)
11	QHUM	Humidification energy input
		(for RESYS and RESVVT: defrost load) (Btu/hr)
12	QDHUM	Sensible dehumidification reheat input
		(for RESYS and RESVVT: defrost load) (Btu/hr)
13	TCMIN	Minimum temperature air handler could supply (F)
14	TCMAX	Maximum temperature air handler could supply (F)
15	QLSUM	Total system latent heat load from LOADS (Btu/hr)
16	QPSUM	Total system light heat to return (Btu/hr)
17	CFM	Total system supply air flow rate (cfm)
18	CFMH	Total system hot supply air flow rate (DDS, MZS, PMZS) (cfm)
19	CFMC	Total system cold supply air flow rate (DDS, MZS, PMZS) (cfm)
20	RCFM	Total system return air flow rate (cfm)

Please add this page to Appendix C of the DOE-2.1E Supplement, after p. C.27.

Surface Vertex Verification Report – LV-N (example)

```
LBL RELEASE OCT 1993       version : 2.1E-107
1˝
      *   1 * diagnostic  WARNINGS ..  $ --- file : ts-poly1.inp ---
      *   2 * input  LOADS ..
1
                      L D L   P R O C E S S O R   I N P U T   D A T A
                            Thu Feb 17 15:23:59 2000LDL RUN  1
      *   3 *
      *   4 * run-period         JAN 1 1974  thru  JAN 2 1974  ..
      *   5 * building-location  latitude=42.0  longitude=88.0
      *   6 *                    altitude=610 time-zone=6   azimuth=30.0  ..
      *   7 * loads-report    verification=(LV-N,LV-C,LV-D,LV-H)
      *   8 * $                  dump-options=(STD-FILES,SIMULATION)
      *   9 *       ..
      *  10 *
      *  11 * CONS1 =    construction  u=1.1  ..
      *  12 * GT1 = glass-type  glass-type-code = 3  ..
      *  13 *
      *  14 * PS =  polygon  (0,0,0)   (80,0,0)  (80,0,40)  (0,0,40)  ..
      *  15 * PS_2D =    polygon  (0,0)     (80,0)    (80,40)    (0,40)     ..
      *  16 * PE =  polygon  (80,0,0)  (80,30,0) (80,30,40) (80,0,40) ..
      *  17 * PE_2D =    polygon  (0,0)     (30,0)    (30,40)    (0,40)     ..
      *  18 * P3 =  polygon  (80,0,0)  (80,60,0) (80,60,40) (80,30,70) (80,0,40)  ..
      *  19 * P4 =  polygon  (0,60,0)  (0,0,0)   (0,0,40)   (0,30,70)  (0,60,40)  ..
      *  20 * PS_2DY=    polygon  (0,0)     (80,0)    (80,40)    (0,40)  ..
      *  21 *
      *  22 * $ Note: EW0 , EW1 , EW2 are identical.
      *  23 *
      *  24 * SPX = space  area=1000  volume=10000  x=100  y=200  z=300  ..
      *  25 *   EWXS0 =  e-w  h=40  w=80  azimuth=180  tilt=90  cons=CONS1 ..
      *  26 *     WINXS0 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  27 *   EWXS1=   e-w  Polygon=PS         cons=CONS1 ..
      *  28 *     WINXS1 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  29 *   EWXS2 =  e-w  Polygon=PS_2D  x=0 y=0 azimuth=180 tilt=90 cons=CONS1 ..
      *  30 *     WINXS2 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  31 *   EWXE0 =  e-w  x=80 y=0 h=40  w=30  azimuth=90  tilt=90  cons=CONS1 ..
      *  32 *     WINXE0 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  33 *   EWXE1 =  e-w  Polygon=PE         cons=CONS1 ..
      *  34 *     WINXE1 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  35 *   EWXE2 =  e-w  Polygon=PE_2D x=80 y=0 azimuth=90 tilt=90 cons=CONS1 ..
      *  36 *     WINXE2 =        window  X=2  Y=4  h=3  w=6  g-t=GT1  ..
      *  37 *   EWX4 =   e-w  Polygon=P3         cons=CONS1 ..
      *  38 *   UWX5 =   u-w  Polygon=P3         cons=CONS1 ..
      *  39 *   IWX1 =   i-w  Polygon=P3  next-to=SPY  cons=CONS1 ..
      *  40 *
      *  41 * SPY = space  area=1000  volume=10000  x=1000  y=2000  z=3000  ..
      *  42 *   EWY1 =   e-w  Polygon=PS_2DY  x=0 y=0 azimuth=180 tilt=90 cons=CONS1 ..
      *  43 * end ..
      *  44 * compute loads  ..
      *  45 * stop ..
1                                                                                            2.1E-107  Thu Feb 17 15:23:59 2000LDL RUN 1

 REPORT- LV-N  DETAILS OF GEOMETRY DATA IN BUILDING COORDINATES
 SPACE.................. (SPACE ORIGIN)
     WALL............... (VERTEX1) (VERTEX2) (...)
         WINDOW......... (VERTEX1) (VERTEX2) (...)
 ------------------------------------------------------------------------------------------------------------------
SPX ................... . (  100.0   200.0   300.0)
     EWXS0   ........... (  100.0   200.0   340.0) (  100.0   200.0   300.0) (  180.0   200.0   300.0) (  180.0   200.0   340.0)
         WINXS0  ....... (  102.0   200.0   307.0) (  102.0   200.0   304.0) (  108.0   200.0   304.0) (  108.0   200.0   307.0)
     EWXS1   ........... (  100.0   200.0   300.0) (  180.0   200.0   300.0) (  180.0   200.0   340.0) (  100.0   200.0   340.0)
         WINXS1  ....... (  102.0   200.0   307.0) (  102.0   200.0   304.0) (  108.0   200.0   304.0) (  108.0   200.0   307.0)
     EWXS2   ........... (  100.0   200.0   300.0) (  180.0   200.0   300.0) (  180.0   200.0   340.0) (  100.0   200.0   340.0)
         WINXS2  ....... (  102.0   200.0   307.0) (  102.0   200.0   304.0) (  108.0   200.0   304.0) (  108.0   200.0   307.0)
     EWXE0   ........... (  180.0   200.0   340.0) (  180.0   200.0   300.0) (  180.0   230.0   300.0) (  180.0   230.0   340.0)
         WINXE0  ....... (  180.0   202.0   307.0) (  180.0   202.0   304.0) (  180.0   208.0   304.0) (  180.0   208.0   307.0)
     EWXE1   ........... (  180.0   200.0   300.0) (  180.0   230.0   300.0) (  180.0   230.0   340.0) (  180.0   200.0   340.0)
         WINXE1  ....... (  180.0   202.0   307.0) (  180.0   202.0   304.0) (  180.0   208.0   304.0) (  180.0   208.0   307.0)
     EWXE2   ........... (  180.0   200.0   300.0) (  180.0   230.0   300.0) (  180.0   230.0   340.0) (  180.0   200.0   340.0)
         WINXE2  ....... (  180.0   202.0   307.0) (  180.0   202.0   304.0) (  180.0   208.0   304.0) (  180.0   208.0   307.0)
     EWX4............... (  180.0   200.0   300.0) (  180.0   260.0   300.0) (  180.0   260.0   340.0) (  180.0   230.0   370.0)
                         (  180.0   200.0   340.0)
     UWX5............... (  180.0   200.0   300.0) (  180.0   260.0   300.0) (  180.0   260.0   340.0) (  180.0   230.0   370.0)
                         (  180.0   200.0   340.0)
     IWX1............... (  180.0   200.0   300.0) (  180.0   260.0   300.0) (  180.0   260.0   340.0) (  180.0   230.0   370.0)
                         (  180.0   200.0   340.0)
 SPY ................... ( 1000.0  2000.0  3000.0)
     EWY1............... ( 1000.0  2000.0  3000.0) ( 1080.0  2000.0  3000.0) ( 1080.0  2000.0  3040.0) ( 1000.0  2000.0  3040.0)
1                                                                                       DOE-2.1E-107  Thu Feb 17 15:23:59 2000LDL RUN  1
```



34
32
30
28
26
24
22
20
18
16
14
12
10
Surface temperature [°C]
0
24
48
72
96
120
144
168
Time [h]